# AN INTEGRATED APPROACH TO IRRIGATION SYSTEM ASSESSMENT AND MANAGEMENT OF SELECTED PROJECTS IN THA CHIN BASIN, THAILAND

By

Sanidda Tiewtoy

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Engineering in Water Engineering and Management

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| Scholarship Donor: | RMUT (Rajamangala University of Technology) |
| Research Grant Donor: | CIRAD (Centre de Cooperation Internationale en Recherche Agronomique pour le Developpement) |

Asian Institute of Technology
School of Engineering and Technology
Thailand
**May 2010**

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# Abstract

This study evaluates the sustainability of two irrigation projects located in Tha Chin Basin, Thailand, namely Kamphaengsaen operation and maintenance project (KPP), and Phophraya operation and maintenance project (PPP). It focuses on the development of irrigation sustainability index (ISI) based on key indicators and provides a basis in formulating management options for improving irrigation sustainability. The assessment of the two projects is based on the investigation of sustainability indicators. These indicators are analyzed using principal component analysis (PCA), whereby dominant indicators influencing irrigation sustainability are identified. Afterwards, the indicators are weighted and computed to obtain an irrigation sustainability index (ISI). The index is used to classify the sustainability of each irrigated area (zone) into five levels. The results for KPP show that net farm income, awareness on irrigation water use, matching of farm operations with RID water delivery, and field application ratio are the major sustainability indicators. Among the 27 zones in KPP, six zones show very low sustainability level, five zones are low, 11 zones are medium, four zones are high and one zone is very high. Four key indicators are found in PPP, which include perception of drained water quality, satisfaction on adequacy of water distribution, flow ratio, and net farm income. Among the 11 zones in PPP, there are four zones that show very low sustainability level; one zone is low, four zones are medium, one zone is high and another one zone is very high. Based on the results of the study, it is evident that each zone or project can be vulnerable to different causal indicators influencing sustainability of irrigation system so there is a need to improve the sustainability of some zones in the two projects. Therefore, this study adopts a modified Driving forces-Pressures-State-Impacts-Responses (DPSIR) framework to describe the links among the indicators influencing sustainability of irrigation system, status and impacts of problem and to formulate management options. The common management options to both projects are establishment and strengthening of water user groups, provision of support and promotion of mutual help, establishment of rules and regulations on water use and collection of irrigation water fee. The specific management strategies for KPP are improvement and flexibility of water distribution schedule. Legislation of agricultural wastewater law and improvement of water delivery plan on the other hand, are the specific management options for PPP. The key indicators identified and the irrigation sustainability map developed based on ISI can be used to formulate management strategies for some zones in the basin which are showing low sustainability levels. It is envisioned that the methodological approach adopted in this study for identifying key indicators influencing sustainability of irrigation system and for evaluating and improving irrigation sustainability might be useful to irrigation managers, policy makers, water users and researchers.


Keywords: Irrigation; Sustainability; Assessment, Indicators; PCA; ISI; DPSIR; Thailand

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## List of Abbreviations

| | |
|---|---|
| AWAM | Area and Water Allocation Model (AWAM) |
| BS | Base Saturation |
| CEC | Cation Exchange Capacity |
| CWREQ | Crop water requirement |
| CO | Community Organizers |
| DPSIR | Driving forces-Pressures-State-Impacts-Responses |
| DEM | Digital Elevation Model |
| DO | Dissolved Oxygen |
| EEA | European Environment Agency |
| EC | Electrical Conductivity |
| FG | Farmer Group |
| GAP | Güneydogu Anadolu Project |
| Ha | Hectare |
| ISI | Irrigation Sustainability Index |
| INCA | Irrigation Network Control and Analysis |
| IWAM | Integrated Water and Agriculture Management |
| IWUG | Integrated Water User Group |
| JMC | Joint Management Committee |
| Kg | Kilogram |
| KPP | Kamphaengsaen Operation and Maintenance Project |
| MAF | Ministry of Agriculture and Forestry New Zealand |
| MDS | Minimum Data Set |
| MOM | Management Operation and Maintenance (MOM) model |
| OM | Organic matter |
| O&M | Operation and Maintenance Project |
| PPP | Phophraya Operation and Maintenance Project |
| PCA | Principal Component Analysis |
| PCs | Principal Components |
| PIM | Participatory Irrigation Management |
| R&D | Research and Development |
| Rh | Relative Humidity |
| RID | Royal Irrigation Department |
| RIO | Regional Irrigation Office |
| SIMIS | Scheme Irrigation Management Information System |
| WUG | Water User Group |
| WUOs | Water User Organizations |
| WUA | Water User Association |
| WUC | Water User Co-Operative |

# Chapter 1
# Introduction

## 1.1 Background

During the past two decades, the population of Thailand has increased rapidly and economic activity has significantly expanded resulting in increasing demand for water by all sectors such as agriculture, industry and domestic. Although many water resource development programs have been implemented continuously for more than 80 years, water demand for all purposes has exceeded the supply because of rapid rural development, industrialization, expansion of tourism and deteriorating water quality due to excessive use of fertilizer and pesticides, urban sewage and others. Planning development and management of water resources are critical to sustain future economic growth in Thailand. At present, water resources will continue playing a fundamental role in meeting the growing water demand for domestic consumption, agricultural and industrial production, and hydropower generator, as well as tourism sector. The irrigation systems in Thailand are quite old and mostly of diverse type. The operation and maintenance of the main system and lateral canals to the farm turnouts has been under the jurisdiction of the Royal Irrigation Department (RID). The water user groups which are formed among the farmers receiving irrigation water from the same lateral. These groups take care of the operation and maintenance as well as water management at the farm level in the area. Several water user groups join to form a water user association. The government has implemented irrigation policies to improve water use efficiency of existing irrigation projects instead of constructing new irrigation systems. According to Decentralization Act 1999, RID has transferred all small irrigation systems to the Tambon Administrative Organization (TAO) in 2003. TAO is, therefore, responsible for the supervision of WUGs in operation, maintenance and water distribution, not only the ditch and dike project level, but also pumping irrigation project level. Therefore, since 2001 to 2005, the small scale systems administration transferred from RID to TAO which supports budget for canal cleaning and weed control.

According to the country's nine-point water policy and visions, RID proposed an implementation plan for sustainable development. One of the plans was the provision of an extensive and equitable raw water resource for the farmers. This plan served as a response to the growing water demand for agricultural and domestic uses in the country. The plan made major changes in 1997 when Thailand experienced a crisis that resulted in economic recessions and budget shortages. In the mentioned year, RID concentrated more on the improvement of water use efficiency of existing irrigation projects rather than on the development of water resources and expansion of irrigable areas (Budhama et al., 2001).

Under sustainable development approach, irrigation management is dependent not only on engineering and technical improvements but also integration with agriculture, economics, institutional and social aspects of the region.

## 1.2 Problem Statement

Thailand is one of the top of rice exporters in the world (IRRC, 2009). However, as a main economic crop, rice still has quite low production efficiency. In this regard, there is a need of additional research and development (R&D), improvement of fundamental structures and water management, quality control in production and expanded marketing (Budhama et al., 2001).

Several reports reported key problems affecting irrigation system management in Thailand (Suiadee, 2000; Budhama et al., 2001) which include:

- lack of water law,
- lack of water fee structure for agricultural sector,
- off-schedule water delivery (farmers do not follow RID's plan),
- inadequate financial support to various projects;
- lack of effective service delivery programs at the main system level,
- lack of cooperation among farmers,
- lack of coordination among governmental agencies,
- lack of communication and coordination between farmers and RID and
- infrastructures are not functioning well due to canal leakage, sediment, etc.

Tha Chin Basin was considered as a critical basin in the Central region based on the report, "The Master Plan for Development of water Resources and Rehabilitation of the Existing Irrigation Project for the 9$^{th}$ National Economic and Social Development Plan"(RID, 2003). The study covered a detailed analysis of all 25 basins in terms of the supply potential and water demand of each basin. Tha Chin Basin was selected as a study area based on the criteria indicated. Tha Chin Basin is a source of rice production, an economic crop of Thailand. Other problems identified in this basin is as follows; a) lack of water retention but high water requirement b) diversion of water from Mae Klong basin to Tha Chin Basin has decreased c) water quality is a serious problem. There is a need to develop its water resources and rehabilitates its existing irrigation project.

Several studies on irrigation sustainability and the use of analytical and statistical frameworks for deriving key sustainability indicators are reviewed by Zhen and Routray (2003). Stockle et al. (1994) used nine attributes in developing a framework that evaluates the relative sustainability of a farming system. Smith and McDonald (1998) proposed some important indicators that assessed the sustainability of farming practices and derived a three-dimensional matrix which can highlight the land uses that represent threats to sustainability. Further, Walker and Reuter (1996) proposed some conditions and trend sustainability indicators where the indicators can assign specific threshold guidelines and expected over-all range.

Becker (1997) reviewed more approaches on sustainability assessment using composite indicators and system-based approaches. The composite indicators approach did not aggregate the indicators into a single dimension while the system-based approach set and applied rules in integrating these indicators in order to achieve a reliable sustainability assessment. Kellett et al. (2005) criticized the reports of RIRDC (1997); MAF (1997); SCARM (1998) and Cai et al. (2001) regarding the presentation of sustainability frameworks into policy-styled documents rather than focusing on particular applications. For example, MAF (1997) suggested considerations of indicators for irrigated agriculture that need interpretation, discussed some possible alternatives and provided overall value of a set of indicators. These indicators should be compared among different farms and measured with a well-documented and acceptable technique. Hence, it would be necessary to develop some techniques for aggregating and applying indicators to a whole arable and irrigated farm.

Based on the need to evaluate the sustainability of irrigation systems, this study attempts to identify key factors such as physical, socio-economic, institutional and environmental factors that affect irrigation system management and then develop irrigation sustainability index (ISI) using principal component analysis (PCA). The PCA was used to identify dominant factors affecting irrigation system management and irrigation sustainability index based on conceptual balancing between socio, economic, institutional and environmental conditions.

According to the above background the research questions which need to be addressed are as follows:

1) What are the indicators influencing sustainability management of an irrigation system?
2) How can we develop an irrigation sustainability index (ISI) in order to assist decision making of irrigation system management?
3) Which dominant indicators would effectively contribute to sustainability of irrigation system as expressed in term of ISI in the study area?
4) How can the irrigation system be managed in order to make it sustainable using ISI?

## 1.3 Hypothesis

1) Sustainability of the irrigation system in Tha Chin basin would be affected by physical, socio-economic, institutional and environmental indicators.
2) Lack of an enabling monitoring of sustainability of irrigation system management would affect the sustainable of irrigation system of Tha Chin basin.
3) Integration of dominant indicators would help develop a meaningful irrigation sustainability index that could keep track of the sustainability of irrigation system management.
4) ISI would help to the understanding of the role and significant influence of key indicators and their implication for irrigation sustainability management in the study area.

## 1.4 Rational of the Study

Increasing economic development and population growth in Thailand is causing some impacts on water resource planning development and management. Irrigation has played and will continue to play an important role in securing the food supply for the rapidly expanding population. In order to cover the concept of sustainability, a key connection among the physical development artifacts with the socio-economic and biological environment are involved (Charles, 1994).

In this study, an approach for assessing irrigation sustainability based on key indicators (e.g. physical, socio-economic, institutional and environmental categories) will be adopted for the selected zones of Tha Chin Basin. The methodological approach will integrate the dominant indicators mentioned earlier and determine its effect on irrigation sustainability. The ISI developed is envisioned to contribute towards the understanding of the role and significant influence of key index and factors and their implication for irrigation sustainability management in the study area. The method may help policy makers, and organizations working on the development of irrigation systems. The methodological approach can be utilized for other areas which have all the data needed for estimating sustainability of irrigation systems (e.g. physical characteristics, socio-economic, institutional and environmental conditions).

### 1.5 Objective of the Study

This study attempted to identify the key factors such as physical, socio-economic environmental and institutional factors affecting irrigation system management and to develop a methodology for determining irrigation sustainability index (ISI) using principal component analysis (PCA) and then provided a basis in formulating management options for improving irrigation sustainability using a modified DPSIR (Driving force, Pressure, State, Impact and Response) framework. To achieve this, the specific objectives of this study are as follows:

1) To identify factors affecting the management of irrigation system in selected projects of Tha Chin Basin.
2) To develop a methodology for generating an irrigation sustainability index based on key indicators.
3) To assess the sustainability of irrigated areas in selected projects of Tha Chin Basin based on ISI.
4) To formulate management strategies for sustainable irrigation management based on a modified DPSIR framework.

### 1.6 Scope and Limitations of the Study

The following scopes and limitations were expected.

1) Kamphaengsaen O&M project (KPP) and Phophraya O&M project (PPP) were selected as the study area based on their location and crops; both are located in Tha Chin Basin.
2) The data collection was carried out through field survey, field measurement, farmer's interview and available documents. Financial factor and water quality from farmer's field and groundwater degradation were not considered.
Financial indicator and water quality from farmer's field and groundwater were not considered.
3) The factors and indicators were classified into four groups namely: physical, socio-economic, institutional and environmental categories.
4) The principal component analysis (PCA) was applied to identify dominant factors affecting irrigation system management and to identify indicators influencing sustainability of the irrigation system of two projects to bring out the management options for stakeholders and policy makers.
5) Some management strategies were sought to propose based on a modified DPSIR (Driving force, Pressure, State, Impact and Response) framework.

# Chapter 2
# Literature Review

This study aimed at identifying key factor affecting irrigation system management and assessing the sustainability of irrigated area based on irrigation sustainability index using principal component analysis. This chapter provides concept and study reported by researchers based on their research and expertise. A review of literature related to factor affecting irrigation system, irrigation sustainability, principal component analysis and institutional policies of Royal Irrigation Department are presented.

## 2.1 Factors Affecting Irrigation System Management

Irrigation design and management decisions are the result of a complex interaction of many variables which are consistent between individuals. Other decisions (e.g. frequency of irrigation, depth of water to be applied) are common to all systems and dependent on the nature of crop, soil and environmental conditions (Raine, 2000).

Irrigation management is often designed to maximize efficiencies and minimize the labor and capital requirements in a particular irrigation system while maintaining a favorable growing environment for the crop (Walker and Skogerboe, 1987). There is a large number of considerations in the selection of an irrigation system. These considerations include the compatibility of the system with other agricultural operations, economic factors, topographic limitations, soil characteristics, water requirement and supplies and external influences. Economic factors involve fixed cost (land renting) and operation cost (energy, land preparation, maintenance, labor, taxes, etc.).

Topographic limitations include location and relative elevation of the water source, shape and slope of the field. Soil characteristics include the soil type, soil moisture-holding capacity and soil properties which respect to water supplies, the quality, quantity and temporal distribution characteristics of the source of irrigation water have a significant bearing on the irrigation practice. External influences cover foreign exchange, outside donors and lenders.

According to Subramanian et al. (1997), the water user association (WUA) is envisaged as the intermediary between physical, technical, social, economic and policy, agency aspects of water reform the actual irrigation performance as shown in Figure 2.1. Physical and technical aspects include the environmental factors, such as the availability of water, the climate and the existing infrastructure. Social and economic considerations include farming communities, the ethnicity of the area, conflicts in the area, the crops grown and access to domestic and international markets. Policy and agency aspects include the type of regulatory authority, the extent to which agency involvement is a key to upstream water system management, the efficiency and professionalism of the existing agency, extent to which agency functions are publicly accountable.

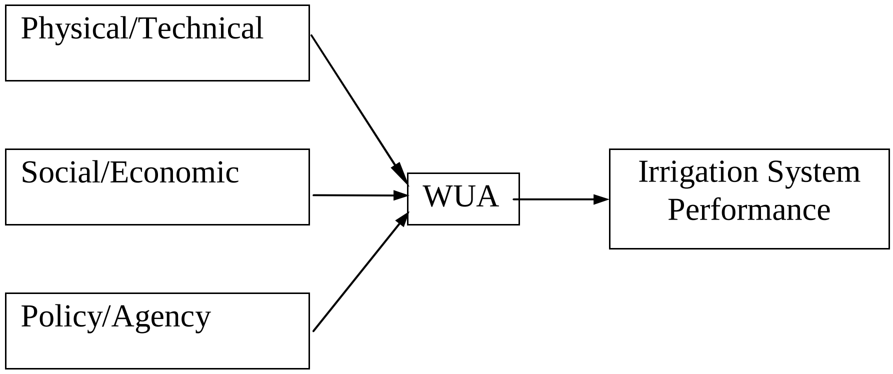



Figure 2.1 Factors affecting irrigation system management
Source: Subramanian et al. (1997)

Rosegrant et al. (1999) proposed a conceptual framework in analyzing how the physical, socio-economic, policy and environments affect the institutions and laws that govern water allocation as illustrated in Figure 2.2. The underlying conditions are seen to affect the choice of water allocation mechanisms and institutions. The conditioning factors are broadly defined to include: 1) physical and technical factors, including quantity and quality of water supply, soils, terrain and water application and measuring technology; 2) economic and social factors including markets, landholding size, population density, and heterogeneity of social background ; and 3) policy and institutional factors, including water rights, pricing, regulations, capacity of government agencies, organizational density and legal frameworks.

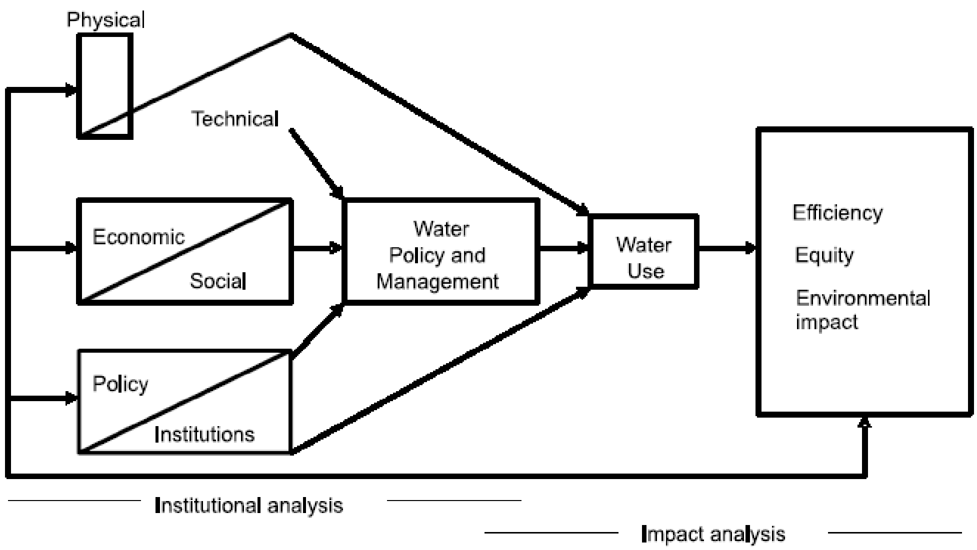



Figure 2.2 Policies and institutions at river basin and irrigation system
Source: Rosegrant et al. (1999)

Raine (2000) described for irrigation design and management practices are influenced by a wide range of factors including:

1) Agronomic (e.g. crop responses to climatic and soil moisture variables)
2) Environmental (e.g. climate, soil, topography)
3) Social (e.g. experience, education, labour availability)

4) Economic (e.g. capital availability, operation costs, returns from product)
5) Historical (e.g. existing infrastructure, previous farming systems)
6) Hydrological (e.g. river flow regimes, groundwater issues, surface flow harvesting)
7) Engineering constraints (e.g. hydraulic design limitations on pumps, pipes and storages, supply capacities)
8) Regulatory policy (e.g. legislation on access to river, surface and groundwater)
9) Administrative procedures (e.g. licensing requirements, ordering of water supplies)

Furthermore, Bagadion (2000) identified factors affecting the role of WUAs as follows:

1) Laws and policies of the country and its irrigation agency
2) Size and complexity of the irrigation systems
3) Physical condition of the irrigation systems
4) Size of irrigated farm holding
5) Farmers net income
6) Capability of irrigation agency and its staff
7) Capability and organizational arrangements of the WUA
8) Local politics
9) Local social customs and practices
10) Frequency of natural disasters
11) Environmental problems

## 2.2 Irrigation Sustainability

### 2.2.1 The definition of sustainable irrigation system

Various agencies and researchers have suggested many definitions of sustainability for irrigation and agriculture. The United Nations Food and Agriculture Organization (FAO, 1989) indicated that sustainable development is the management and conservation of the natural resource base, and the orientation of technological and institutional of human needs for present and future generations. Such sustainable development in the agriculture, forestry and fisheries sectors conserves land, water, plant and animal genetic resources, is environmentally non degrading, technically appropriate, economically viable and socially acceptable.

Ball and Popiel (2001) indicated that sustainable agriculture is a management philosophy and system providing for agricultural needs of current and future generations. Sustainable agriculture utilizes management practices that are profitable, environmentally sound, and beneficial to society. Cullen (2004) guided for irrigation to be sustainable irrigation and drainage must be conducted in a way that does not degrade the quality of land, water and other natural resources that contribute to both agricultural production and environmental quality. Hill and Tollefson (2003) said that should irrigated agriculture be practiced in the future, for it to be sustainable, socially, economically and environmentally viable, institutions must adapt to compatible concepts of sustainability.

Izac and Swift (1994) reported by Kellett et al. (2005) proposed initial and revised sustainability definition for agriculture. They initially defined a sustainable cropping system as one that achieves an acceptable level of production of harvestable yield, which shows a non declining trend from cropping cycling to cropping over the long term. Their revised definition includes the following element:

- Sustainability at a range of spatial scales (field, farm and village) – equity between members of the current generation.
- Sustainability of all farming system outcomes (products, by products and ecological impacts) – balance between system elements
- Capacities of ecosystems to respond to change – system limits
- Sustainability of farming system in the context of change – change occurs through system processes.

MAF (1997) indicated that an important overall goal which farmers identified for sustainable irrigation was to maximize net profit over the long term. Other key goals were categorized as economic, environmental or social goals.

Following the concept of Kellett et al. (2005), sustainability is an evolving concept:

1) Equity between members of the present generation
2) Equity between members of current and future generations
3) Balance between system elements: social, economic, environmental, institutional, culture and
4) System capacity limits to support human populations

Katona et al. (2005) reviewed the meaning of sustainable development. According to this view there must be no single focus of sustainability, but instead all of the economic, social and environmental systems must be simultaneously sustainable in and of themselves. Figure 2.3 illustrates environmental, economic and social development where the environmental is assumed to define the limits for economic and social development. They added the different capitals to the figure as the three pillars can be measured through these capitals.

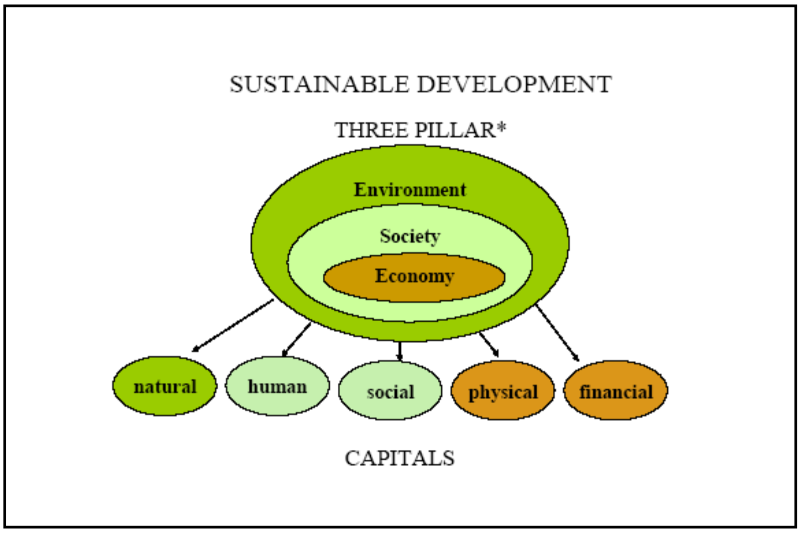



Figure 2.3 Sustainability development

Source: Katona et al. (2005)

These definitions provide some guidelines for planning and management of irrigation system in the study area. Based on information above, definition of sustainability management means balancing between social, economic, environmental and institutional dimensions to meet three goals; environment health, economic profitability and social acceptability using appropriate technology and adopting institutional.

### 2.2.2 Evaluation of sustainability indicators

Sustainability indicators describe aspects of the sustainability of system. Sustainability of various attributes and processes of a system are gauged with different sustainability indicators. Further, different indicators gauge different systems (Kellett et al., 2005). Several studies have proposed indicators for the evaluation of irrigation sustainability using analytical and statistical frameworks. Zhen and Routray (2003) reviewed relevant literatures on these sustainability indicators and these were practically applied by various scholars. For example, Stockle et al. (1994) proposed a framework for evaluating the relative sustainability of a farming system using nine attributes i.e. profitability, productivity, soil quality, water quality, air quality, energy efficiency, fish and wildlife habitat, quality of life, and social acceptance. Their proposed scheme included a list of constraints for each attribute. A system was evaluated by assigning weights to each attribute, scoring the attributes of the proposed system based on the specific constraints of each attribute, and then combining the weights and scores to produce a figure of merit. Smith and McDonald (1998) proposed some important indicators to assess the sustainability of farming practices. From an economic's point of view, they argued that profitability indicators such as total production and net farm income are the primary indicators of agricultural sustainability. From an environmental point of view, they focused on trends in land and water use since these affect long-term production. Increasing water use efficiency, nutrient replacement, maintenance of biodiversity and declining soil loss were viewed as potential sustainability indicators. Social indicators were also equally important for assessing sustainability. They focused on trends in land and water use since these affected long-term production. They argued that there were important threshold values for the assessment of sustainability. The three-dimensional matrix works by highlighting the scales at which land uses represent a threat to sustainability. In addition, Walker and Reuter (1996) proposed a condition and trend to sustainability indicators framework. They used three types of threshold values to evaluate the indicator such as good, fair and poor. The threshold guidelines and the overall ranges expected for each indicator should also be identified. Indicators can thus take into account local conditions and acceptable ranges for the five ranges such as very good, good, fair, poor and very poor.

Moreover, Becker (1997) reviewed the approach to sustainability assessment by composite indicators and system approaches. The first approach, composite indicators was list of indicators without the intent to aggregate or unify them into a single dimension and without assigning different weights to the different composite. The second approach was the system based approaches which applied strict rules of system theory to select a number of system properties as sustainability indicators, and set rules that specified how to integrate them into a meaningful assessment of the sustainability of the system. The examples of this approach are Dalsgaard et al. (1995) and Plet et al. (1995). On the other hand, Izac and Swift (1994) discussed the appropriate scale for sustainability assessment of agricultural system in Sub Saharan Africa. To identify the system hierarchy, externalities between levels and trade off among components can be traced and explicitly taken into consideration.

Moreover, MAF (1997) proposed sustainability goals for irrigated agriculture were economic, environmental and social goals. The indicator considerations were to determine which the data provide some interpretation, discuss possible alternatives and provide an overall value for the set of indicators. The indicators must be comparable between farms and different farming sectors and should be measurable with a well documented and accepted technique to ensure repeatability and consistency across farms. Therefore, there was a need to develop techniques to aggregate indicators to a whole farm level for arable and mixed farms.

MAF (1997) suggested list of indicator to assess the sustainability of irrigation system as shown in Table 2.1.

Table 2.1 Suggested List of Major Indicators

| Indicators | Ability of variable | Unit |
|---|---|---|
| Economic | - Profit per unit of water used<br>- Requires net profit after tax and/or gross margin per hectare | $/m^3$ |
| Production | - Production per unit of water<br>- Requires quantity of produce per hectare for each crop or product<br>- Quality of produce | t or kg/m$^3$<br>t or kg/ha<br><br>% in each grade |
| Energy | - Energy used per unit of water<br>- Requires annual energy usage | kWh/m$^3$<br>kWh |
| Labour | - Labour units per irrigated hectare for year<br>- Possibly peak labour demand | Hours/ha<br>Hours/week |
| Water | - Daily volumes of water flowing on to farm for each crop<br>- % of water stored in the root zone<br><br>- Ratio of water depth applied (D) to rainfall corrected water demand ET<br><br>- Depth applied/evapotranspiration<br><br>- Number of days crop stress as shown by neutron probe monitoring<br><br>- Maximum water abstraction rate each season<br><br>- Daily visual assessment of pond or run-off | m$^3$/day<br><br>Requires soil monitoring<br><br>mm/mm<br><br>Rainfall<br><br>Doesn’t detect short-term under- or over-irrigation<br><br><br>m$^3$/day |
| Environmental | - Resource consents obtained and complied with record of abatement notices | |
| Soils | - Aggregate stability<br>- Water-holding capacity | Required for planning irrigation |

Source: MAF (1997)

Bell and Morse (1999) proposed a modified version of the AMOEBA for sustainability analysis. They suggested that AMOEBA modified for irrigation sustainability indicators. A range was created with two circles instead of one. The inner circle depicts the lowest acceptable value for sustainability indicators and the outer circle depicts the highest acceptable value for the sustainability indicators. Threshold range values are determined by using existing guidelines. The zone between the concentric circles is depicted as sustainable, while the area outside this zone is unsustainable.

Following the concept of Cai et al. (2001) a set of manageable indicators of sustainability are necessary to detect problem as they arise and to provide an early warning system for decision makers. The indicator should be monitored and measured on the basis of the performance of natural systems. In particular the indicators should be helpful in tracing long term cumulative environmental changes due to irrigation practices, which can potentially create irreversible problems. Sustainability in irrigation water management can be indicated by

- Water supply system reliability, reversibility, and vulnerability

Reliability comprises three terms: occurrence reliability (the ratio of the number of periods of system success to the number of periods of operation), temporal reliability (the ratio of time of the system is in the success state to the total time of operation), and volumetric reliability (the ratio of the volume of water supplied to the total volume demand).

Reversibility is the probability of the system can recover from failure to some acceptable state within a specified time interval.

Vulnerability represents the severity or magnitude of a system failure.

- Environmental system integrity

Indicators for environmental system integrity fall into three categories:

1) Health of aquatic and floodplain ecosystems. Extensive irrigation can affect drinking water health as indicated by bacteria, nutrients, and toxic contaminants and soil health as indicated by soil's water holding capacity, total organic Nitrogen and Carbon, Ph value and the condition of surface aggregates.

2) Water quality; Irrigated agriculture affects water quality in several ways, including higher chemical-use rates associated with irrigated crop production, increased field salinity resulting from applied water, accelerated pollutant transport with drainage flows, groundwater degradation due to increased deep percolation to saline formation, and greater in stream pollutant concentration due to flow depletion.

3) Soil degradation; Irrigation responsible for soil water logging and salinization in many regions where drainage systems are poor, irrigation with traditional furrow systems also causes soil erosion that can be measured by the extent of topsoil losses.

- Equity in water sharing

Equity involves complex natural, political, and socio-economic factor such as, conflict between upstream and downstream and various water users.

- Economic acceptability

Economically acceptable irrigation systems provide lifestyle and social option for farmers and also contribute to the wider economy and community.

Hill and Tollefson (2003) claimed that for irrigation project to be economically sustainable in the long run, they must create enough wealth and rebuild the systems. In turn, the water users must receive enough income from the sale of their product and be able to pay sufficient water charges.

According to Kellett et al. (2005), some biophysical sustainability indicators relevant to irrigation agro-ecosystems are presented in Table 2.2 which can be used to assess aspects of the biophysical sustainability of irrigation agro-ecosystem at field, farm, district, scheme and catchment scales.

Table 2.2 Sustainability Indicators

| Categories | Indicators |
|---|---|
| Soil Properties | - soil sodicity<br>- pH<br>- soil fertility |
| Water Resources | - water supply system reliability<br>- water supply system reversibility<br>- water supply system vulnerability<br>- equity in water sharing<br>- water use efficiency |
| Farming and Irrigation Methods | - matching crop requirements with water application<br>- daily, schedule, and annual water<br>- application rates<br>- chemical applications<br>- frequency of fertilizer applications<br>- field application ratio (water) |
| Climate | - seasonality of rainfall<br>- flooding frequency |

Source: Kellett et al. (2005)

Based on the indicators significant contribution to sustainability as reported in literature review, most of indicators were considered in this study as shown in Table 3.4.

## 2.3 Principal Component Analysis

### 2.3.1 Concept and definition of PCA

Principal component analysis is a statistical technique applied to plural sets of variables to discover similarities and positioning of the variables. This technique involves a mathematical procedure that transforms a number of (possibly) correlated variables into a (smaller) number of uncorrelated (independent) variables called principal components. The objectives of principal component analysis are to discover or to reduce the dimensionality of the data set and to identify new meaningful underlying variable.

PCA is included in the SPSS package as a data reduction technique. It takes a large set of variables and looks for a way that the data may be reduced or summarized using a smaller set of factor or component. In principal component analysis the original variables are transformed into a smaller set of linear combinations, with all of the variance in the variables being used (Pallant, 2005).

It transforms the data to a new coordinate system such that the greatest variance by any projection of the data comes to lie on the first coordinate (called the first principal component), the second greatest variance on the second coordinate and so on. The first principal component accounts for as much of the remaining variability as possible. This procedure performs principal component analysis on the selected dataset. Principal component analysis is concerned with explaining the variance covariance structure of a high dimensional random vector through a few linear combinations of the original component variables.

Principal component analysis is an available extraction technique that can be used to determine the best model that describes the relationship among the set of variables. To determine the number of factors (the ones that describe the underlying relationship among the variables) the eigenvalue rule or Kaiser’s criterion (only factors with an eigenvalue of 1.0 or more are retained) is used. The eigenvalue of a factor represents the amount of the total variance explained by that factor.

According to Smith (2002), PCA is a statistical technique applied to plural sets of variables to discover similarities and positioning of the variables.

### 2.3.2 Application of principal component analysis

Ehrenberg (1982) pointed out the usefulness of principal component analysis (PCA) for indexing as the PCA can help to reduce the dimension of data set and to identify new meaningful underlying variable with data reduction technique PCA can help to develop composite index. Ishizuka et al. (2003) identified the agricultural conditions in each district of Lao PDR and formulated the Master Plan of Integrated Agricultural Development in Lao PDR. The multivariate analysis was applied for this study using GIS technique. PCA provided them only principal component scores. The interpretation and naming of principal components derived should be done by the expert.

According to Andrew et al. (2002), there are many documented strategies for using PCA or closely related factor analysis to select a subset from a large data set. They used PCA for soil quality assessment then created Soil Quality Index (SQI) formula as shown below:

$$SQI = \sum_{i=1}^{n} W_i * S_i \tag{2.1}$$

Where

W = The PC weighting factor
S = The indicator score

It assumed the high value of principal components (PCs) which best represent the system attribute and examined only the PCs with eigenvalues ≥1. The SQI was calculated using weighting factor and the indicator score as shown in Equation 2.2.

$$SQI = 0.61xS_{somi} + 0.61xS_{Eci} + 0.16xS_{pHi} + 0.16xS_{wsai} + 0.14xS_{zui} + 0.09xS_{BDi} \quad (2.2)$$

Where

S = The score for the subscripted variable
W = Weighing factors
SOM = Soil organic matter
EC = Electrical conductivity
pH = Soil pH
WSA = Water-stable aggregates
Zn = Zinc
BD = Bulk density

Halim et al. (2006) used PCA for soil erosion hazard assessment in the Upper Kalingarang Watershed, Indonesia. PCA was used to group the 18 biophysical and socio-economic variables. There were seven principal components which were defined as erosion hazard key factor with significant loading (eigenvalues ≥1). Five and two key factors were biophysical and socio-economic factor, respectively. These key factors were used in formulating a soil erosion hazard index (EHI) equation which relates a number of key factors consisting of biophysical and socio-economic variables, namely soil texture, slope steepness, land cover, soil conservation practice, income and farmer's knowledge. Weighing and scoring of these key factors were used to develop EHI based on the equation below:

$$EHI = \sum_{i=1}^{n} W_i * X_i \quad (2.3)$$

Where

W = The PC weighting factor
X = Key factor score

The EHI equation was developed for each land unit as follows;

$$EHI = 0.18S_{(y)} + 0.14LS_{(y)} + 0.11C_{(y)} + 0.11I_{30(y)} + 0.09P_{(y)} + 0.19FPE_{(1-y)} + 0.18In_{(1-y)} \quad (2.4)$$

Where

EHI = Erosion hazard index
S = Silt
LS = LS factor
C = C-factor
P = P-factor
$I_{30}$ = Maximum 30-min rainfall intensity
FEP = Farmer's perception on erosion
In = Income
y = (x-s) / (1.1t-s), a 0-1 score of key factor with more value means higher contribution to erosion hazard
y = 1- ((x-s)/1.1t-s)), a 0-1 score of key factor with the less value means higher contribution to erosion hazard

Moreover, Singh et al. (2007) also used factor analysis, one of the many extraction methods in PCA applied to the data set of water quality obtained from Couala River, India. Factor analysis identified the significant sources of the water quality inputs to the cross section of this river. The results in a huge and complex data matrix comprised of a large number of physical-chemical parameters which were often difficult to interpret and drew meaningful conclusions. Although there are five principal components (PCs) with eigenvalue ≥1, they selected four factors for interpretation namely water temperature, chloride, total dissolved solids (TDS) and dissolved oxygen (DO) contents. In summary, factor analysis was able to identify significant sources of water quality inputs to Couala River.

Based on the examples above, PCA is one of the strong tools which can be used to develop a sustainability index from many variables.

## 2.4 Institutional Policies of Royal Irrigation Department

The Royal Irrigation Department (RID) has been entrusted with the duty on water such as to store and conserve, to regulate, to distribute, to release or allocate for agriculture, energy, domestic consumption, industry and also including prevention of damage it caused, and inland navigation within irrigation area. A detailed organization structure of Royal Irrigation Department is given in Figure 2.4.

### 2.4.1 Strategies of the Royal Irrigation Department (2005)

1) Sufficient supply of irrigation water for agriculture. This strategy is aimed at extending irrigation system to cover the country's agricultural areas by the construction of large scale and medium scale irrigation projects as water development for rural and community area projects. However, all factors concerned shall be prepared in advance for the readiness for the project construction and construction efficiency.

2) Development of water hazard prevention system. The department will support the development of efficient water hazard prevention and mitigation system by the construction of facilities that can prevent and mitigate water hazards and the installation of warning system.

3) Encouragement of efficient people participation in water management. Aiming at increasing quality of life of farmers at all levels, the department realizes that to render good irrigation service to the farmers, the department shall increase the efficiency of its irrigation projects and its administration as well as encouraging participation of all concerned sectors in water management.

### 2.4.2 Organization structure of Royal Irrigation Department

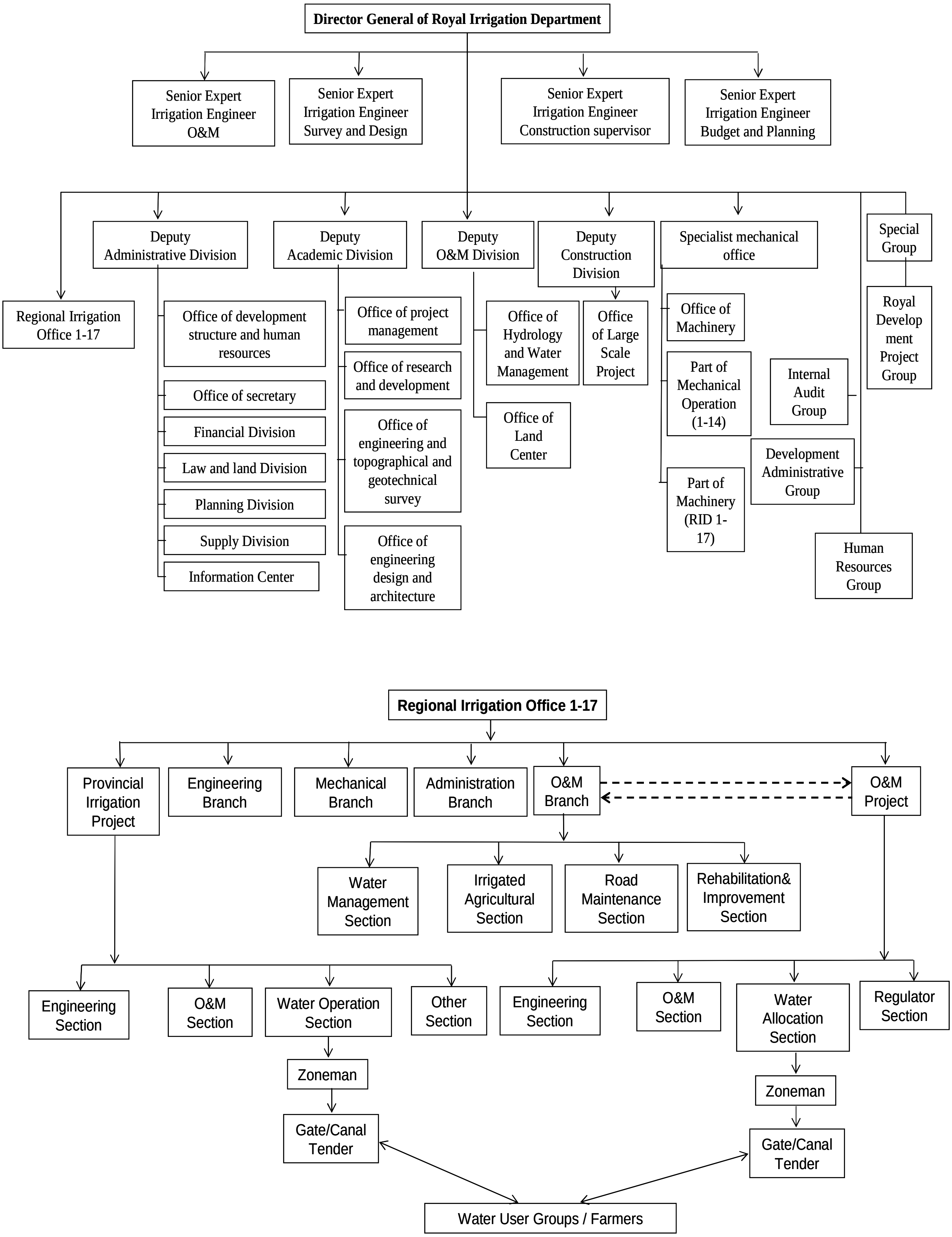



Figure 2.4 Organizational structure of the Royal Irrigation Department

Source: (RID, 2007)

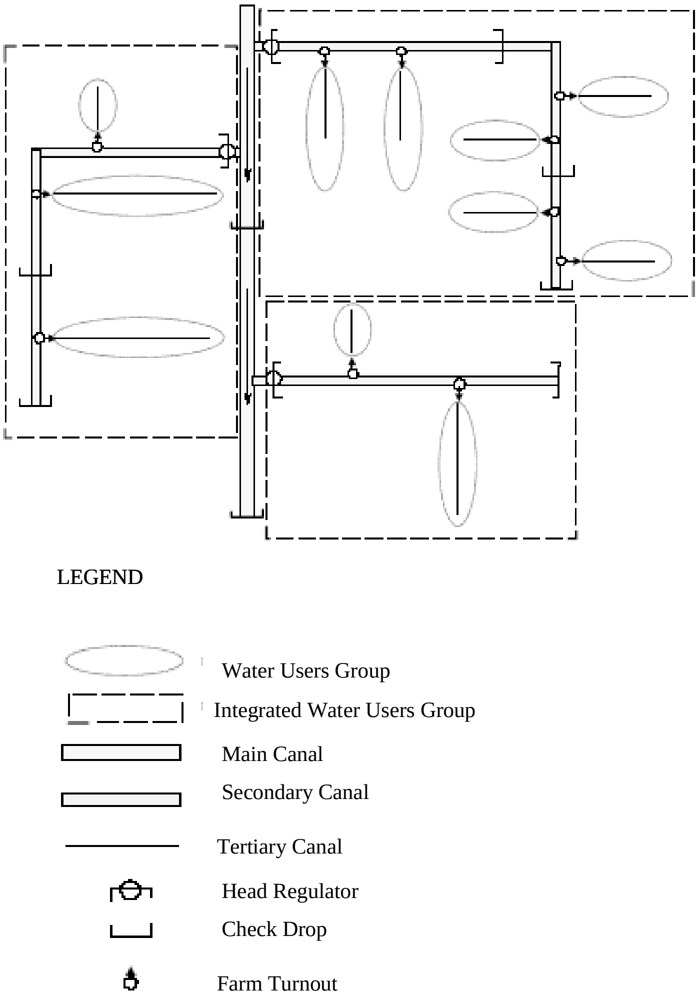



Figure 2.5 Organizational of water users in irrigation system

### 2.4.3 Water users organization in irrigation system in Thailand

The water users organizations (WUOs) of irrigation system in Thailand has been implemented starting in the late 1980s by the Royal Irrigation Department (RID), to organize farmer governed operation and maintenance on tertiary level (one water user group (WUG) for one service unit) while main system operation and maintenance project has remained under the regime of RID (Höynck and Rieser, 2002).

Water user organizations (WUOs) as shown in Figure 2.5 are classified into two groups i.e. formal and informal organization. The details of WUOs are described as below;

- **Informal organization**

- Water Users Group (WUG); boundary area of WUG is not more than 1,000 rai (6.25 rai = 1 ha), it ranges from about 250 rai to 500 rai and the areas cover the tertiary canal.
- Integrated Water Users Group (IWUG); boundary area of IWUG not more than 20,000 rai per group and it covers the secondary canal level.

- **Formal organization**

- Farmer Group (FG); purpose is to share their financial, technical, material, and human resources for the agriculture. It can allocate benefit and bonus to farmers, RID staffs, committee and farmer staffs.

- Water Users Association (WUA); boundary area is same with water users group (WUG). The main purpose is to manage irrigation system. They can not allocate benefit to farmer.

- Water Users Co-operative (WUC); it is responsible for operation and maintenance of a water system. They can allocate benefit to memberships.

### 2.4.4 Participatory irrigation management (PIM) in Thailand

Rattanatangtrakul (2007) reported that Royal Irrigation Department (RID) as the main organization responsible in water management in Thailand, pay much attention in restructuring both the administration aspect and irrigation water management for situation appropriation and change in the future. RID made decision to emphasize new approach of irrigation water management to change the way of irrigation water management from the overall responsibilities of the government organizations to the joint responsibilities with some degree of farmer's participation that is Participatory Irrigation Management (PIM).

The objective of PIM implementation in RID as follows:

1) Harmony of construction or improvement of irrigation system to meet the farmers' need.
2) Farmers and local administrative organizations are conscious of the ownership of irrigation project.
3) Increasing the effectiveness of irrigation water management considering farmer's needs, overall distribution, equity and economy.
4) Encouraging and strengthening the roles of farmers and local administrative organizations.

The process of participatory irrigation management consists of 11 activities as follows:

1) Public relation
2) Setting participatory agreement
3) Establishing water user's group (basic group)
4) Strengthening water user's organizations
5) Upgrading water user's organizations
6) Establishing joint management committee
7) Establishing irrigation repair and improvement fund (IRI fund)
8) Contracting out maintenance works
9) Water delivery and maintenance participation

### 2.4.5 Experiences with PIM in Thailand

Rattanatangtrakul (2007) reported that Royal Irrigation Department (RID) pay much attention in restructuring both the administration aspect and irrigation water management for situation appropriation and change in the future. In case of irrigation water management, RID intends to change the way of irrigation water management from the overall responsibilities of the government organizations to the joint responsibilities with some degree of farmer's participation. RID also made decision to emphasize new approach of irrigation water management, which is Participatory Irrigation Management (PIM).

Suiadee (2000) discussed that, over the last two decades several pilot experiments have been implemented in Thailand. Community Organizers (CO) were recruited to work directly with farmers to establish and strengthen water users associations and promote their participation in the operation and maintenance of tertiary units of medium and large scale irrigation systems or entire small scale irrigation schemes.

Essentially all of these pilot experiences of using CO to create and strengthen water users associations have failed to produce sustainable, self-reliant WUO. Pilot PIM interventions have sometimes succeeded for a time but farmer organizations and artificial government "partnerships" with them have all collapsed after the end of the projects. Like government construction projects, pilot interventions for PIM have also been over-designed. WUO were never empowered with legal status or the authority to define what services they would get or to decide who would provide it.

### 2.4.6 New Approaches in Irrigation management by RID

The RID also introduced new approach in irrigation management as follows;
(Budhama et al., 2001)

1) Introducing appropriate technology in conjunction with local technology, adapting to partially or fully automated systems, for validity, reliability, speed and equity support through an entire network or sub networks.
2) Using equipment to replace skilled labor or local labour attracted from agriculture to industry.
3) Decreasing water loss in canal systems by using concrete lining or by replacing pipe system.

Additional approaches that Thailand has been implementing include;

1) Reducing water loses due to inefficient water resources management, expanding storage farm pond capacity (both as supplementary sources and as night storage)
2) Altering criteria or redesigning proper and easily operated irrigation works.
3) Developing flood management and adjusting paddy cropping systems suitable for lowland areas.
4) Privatization and irrigation management transfer (IMT). Government plays a role as the technical advisor, supporting productivity improvement and directing implementation according to policy to maintain fair procedures.
5) supporting entrepreneurship, ownership and partnership by encouraging farmers to undertake self - maintenance and cost sharing;

6) Replacing function structures by 'process structures' to create a system of participatory agencies.

## 2.5 Irrigation Management

Irrigation system management refers to the proper utilization of irrigation water, through an efficient method of distribution, and on farm application. The term “Water Management” does not only mean the flow of water in the canal or simply irrigating a field, rather it include the management of knowledge skills and incentives to make appropriate use of water, activities related to crop management like choice of cropping patterns or timing of different agricultural operations (Barker et al., 1984). Operation is the control of water, its movement from the source of supply to its point of use in the disposal, if necessary after it has served its purpose. Maintenance is the activity done to guarantee the function of a system at its intended level.

Uphoff (1986) expressed that irrigation management activities can be focused (a) On the water itself (b) On the physical structures that capture convey, distribute and remove water (c) On the social organization that manages these physically defined activities which are interactive and interdependent. The objective of water users on the other hand are shaped by micro-economic considerations, the maximization of household benefits (adequate reliable water deliveries to preferred crops), the minimization of household costs and diminish the environmental degradation. In assessing cost and benefits, economic factors are important but they are not the only ones since the other social and physical consideration also comes into play for water users.

Modernization of an irrigation system can be define as the act of upgrading or improving the system capacity to enable it to respond appropriately to the water service demands of the current times, keeping in perspective future needs (Facon, 2002). Modernization of irrigation systems is already an integral part of Malaysia’s water resources management strategies and is one of the measures being studied at present in Thailand.

The new mapping system and services for canal operation techniques (MASSCOTE) approach has been developed on the basis of extensive experience with irrigation modernization programs in Asia between 1998 and 2006 (Renault et al., 2007). The MASSCOTE methodology has been developed to assist technical expert, irrigation managers and irrigation professionals engaged in the difficult task of modernizing or re-engineering the irrigation management of medium to large irrigation-canal-system.

The examples of irrigation management from the other countries are given as below;

### 2.5.1 Irrigation and management in Turkey and in the Güneydogu Anadolu Projesi (GAP)

Alemdaroglu (2009) summarized that identifying a management, operation, and maintenance (MOM) model was tested to solve the problems in the GAP region. Activities of this project involved effective water use, demonstrations of modern irrigation methods, irrigated-agriculture agronomy, training and extension and the application of the MOM model, based on a bottom-up approach. The problems in this project are institutional and technical. The inadequate participation of water users is the main problem of institutional issue. The farmers are unaware of their responsibilities and rights in the irrigation districts, the organization that distributes water, the department collecting irrigation charges, and the ways it uses the money.

The rules and regulations are deficient. The details of regulation describe the duties and responsibilities of the council and board chair. On the other hand, these do not mention the duties and responsibilities of the secretary-general, personnel in charge and irrigators. There was no law or regulation in place that allows irrigators to inspect the irrigation district. Significant problems are encountered in the collection of water charges, and personnel have problems with job security, and this adversely affects their confidence in the organization.

The MOM management model used to organize the operation and maintenance of irrigated agricultural systems in GAP. It is a continuous management process of planning and designing of irrigation and drainage systems. Focusing on the most appropriate and effective institutional form for each core components is critical e.g. using regulation, training and demonstrating increase. The results of the trial were eagerly awaited. It was anticipated by increasing early awareness of the beneficiaries to the scheme and reduces the problems experienced in the project. In effect the farmers will be ready and responsive when irrigation commences both in the field and in the management organization they establish.

### 2.5.2 Tertiary level irrigation system management in the Chambal Project by water user associations

According to Rao et al. (1998), the Integrated Water and Agriculture Management (IWAM) is a multidisciplinary program aimed at improving and optimizing agricultural production by making efficient use of the available water and land resources with full participation of farmers. It is a systemic approach to irrigation and agricultural management which takes into account the cropping pattern and the various ecological and socio-economic aspects. It involves scientific planning and implementation of practices, on-farm application and management of water, appropriate drainage and maintenance of irrigation and drainage systems.

The key activities of IWAM for implementation in the Chambal project are included;

1) Rehabilitation of irrigation and drainage systems, the main considerations are timeliness, reliability and sufficiency of on-farm irrigation water, equitable water distribution and capital investment, and maintenance requirements.
2) Development of appropriate irrigation practices and irrigation scheduling using model to demonstrate improved on-farm water use efficiency.
3) Strengthening of farmer education programs by organizing farmers' meetings, training camps, field displays, participation of farm women and mass awareness campaigns.
4) Development of a participatory approach to the overall water management through the organization of outlet committees and water user associations.
5) Development of a sustainable maintenance program involving water user associations.

### 2.5.3 Computer-aided manual operation and overall water management

Goussard (1995) summarized the computer programs to improve the overall water management and integrate the various agronomic, economic and operational factors affecting the efficiency of water use. They typically combine simulation of crop water requirements, on-farm scheduling and delivery scheduling of main system operation. Three models of this type are described as follows.

The Scheme Irrigation Management Information System (SIMIS) program is essentially an information and evaluation system (Morabito et al., 1995). The reported application to a scheme in Argentina showed that it can be helpful for the managing staff in detecting discrepancies between plans and reality and in localizing the weak points in the physical infrastructure, operation and management of the delivery system.

The Irrigation Network Control and Analysis (INCA) software is both an information and analysis tool for general management and a decision support tool for day-to-day operation of medium to large-scale irrigation schemes (Makin and Cornish, 1996). In particular, it can be used for determining not only optimum delivery schedules according to computed crop water requirements, but also the corresponding operating schedule of the control structures of the main system. Its application to several schemes in Asia, combined with systematic monitoring, has reportedly led to appreciable water savings while at least maintaining and often improving the reliability and equity of deliveries.

The model package described by D'Urso et al. (1996), currently under trial application in Italy, is designed as a decision-support tool combining a mapping of crop water requirements using remote sensing techniques with models simulating the crop-soil system, farmers' irrigation preferences and delivery system operation. It has been specifically developed for on-demand irrigation systems and therefore includes a module simulating behavior of farmer. Such models are useful tools for project planning, design and evaluation, especially in centrally managed projects and in water scarcity conditions.

### 2.5.4 Introduction of water-saving irrigation scheduling through improved water delivery: A case study from China

Xianjun (1995) introduced a new water-saving irrigation schedule to improve water delivery. The experts and technicians from the agency analyzed the reasons causing irrigation water wastage and found that inappropriate irrigation methods and flawed irrigation practices at farm level were the major reasons. Moreover, the analysis has shown that the root cause of irrigation water wastage is low awareness in water-saving irrigation of farmers. Therefore, the management agency decided to start a new program to popularize a water-saving irrigation schedule through involving farmers more in the process of water-saving irrigation scheduling.

The approach applied in the first step in this program is a learning-by-doing approach consisting of two elements namely; demonstration of the new water-saving irrigation schedule and training of farmers. The demonstration emphasized not only experts and technicians but also farmers for working, discussing questions and making decisions together at all stages of the program. The training of farmers was based around field activities with few classroom presentations. The second step in the program is a searching ways to reduce irrigation duties and increase the number of irrigations.

No complex or new technology was used to introduce a new water-saving irrigation schedule in this program besides farmers being involved in the program to work, discuss questions and make decisions together with expert and technicians.

### 2.5.5 Performance assessment of irrigation water: 2.A case study

Smout and Gorantiwar (2005) studied the optimum allocation plans and water delivery schedules for different combinations of these allocation rules with the help of the Area and Water Allocation Model (AWAM) for Nazare Medium Irrigation scheme in Maharashtra State of India. The allocation plans and the corresponding water delivery schedules during the allocation process were estimated with the help of a simulation optimization model for several allocation rules namely; cropping distributions rule, water distributions rule, irrigation interval rule and irrigation depth rule. These are discussed as follows:

1. Cropping distributions rule (free cropping distribution and fixed cropping distribution); in a free cropping distribution, no restrictions are imposed on the crops to be irrigated and hence land and water resources are allocated to those crops. In a fixed cropping distribution there is some restriction on the area to be allocated to different crops, depending on the requirements in the scheme. The land and water resources are then allocated to the crops according to these restrictions.

2. Water distributions rule (free water distribution and fixed water distribution); in a free water distribution, the water distribution to different users is not predefined and hence the allocation plans for this water distribution consist of the allocation to those units which are productive from a water utilization point of view. In a fixed water distribution the water allocation to different users or allocation units is fixed, depending on certain criteria.

3. Irrigation interval rule (interval during wet and dry season); the frequency of irrigation influences the output and hence the allocation plans. Therefore, allocation plans are sets of irrigation interval during wet and dry season.

4. Irrigation depth rule (full irrigation, fixed depth and variable depth irrigation);

1) Full irrigation is the application of the irrigation depth needed to bring the soil moisture in the root zone to field capacity at the time of irrigation.
2) Fixed depth irrigation is the application of a fixed depth of irrigation to each crop grown on different soils in different climatic zones during the entire crop season.
3) Variable depth irrigation is selected to decide the depth of irrigation for a particular crop grown on different soils in different climatic regions and during different crop growth stages.

The performance measures of productivity (in terms of net benefit and area irrigated), equity (in water distribution), adequacy and excess were assessed for these different allocation plans and schedules. These were further compared with the performance measures of the existing rule (fixed depth irrigation at a fixed interval). The analysis revealed that these performance measures are in some cases complimentary and in other cases conflicting with each other. Therefore, it would be appropriate for the irrigation managers to understand fully the nature of the variation in performance measures for different allocation rules prior to deciding the allocation plans for the irrigation scheme.

### 2.5.6 Diagnosing a farm profitability problem

According to Stiles et al. (2007), net income on any farm depends on several factors. Such can be attributed to farm size, physical efficiencies of production, economical efficiencies of production, enterprise combinations, fixed cost structure and commodity marketing. A diagnostic procedure for locating the source of a farm profitability problem is presented in Figure 2.6. Flowchart is used as a troubleshooting guide for identifying sources of profitability problem in a farm business. These approaches assume that a profitability problem does exist and uses the value of farm production as the starting point.

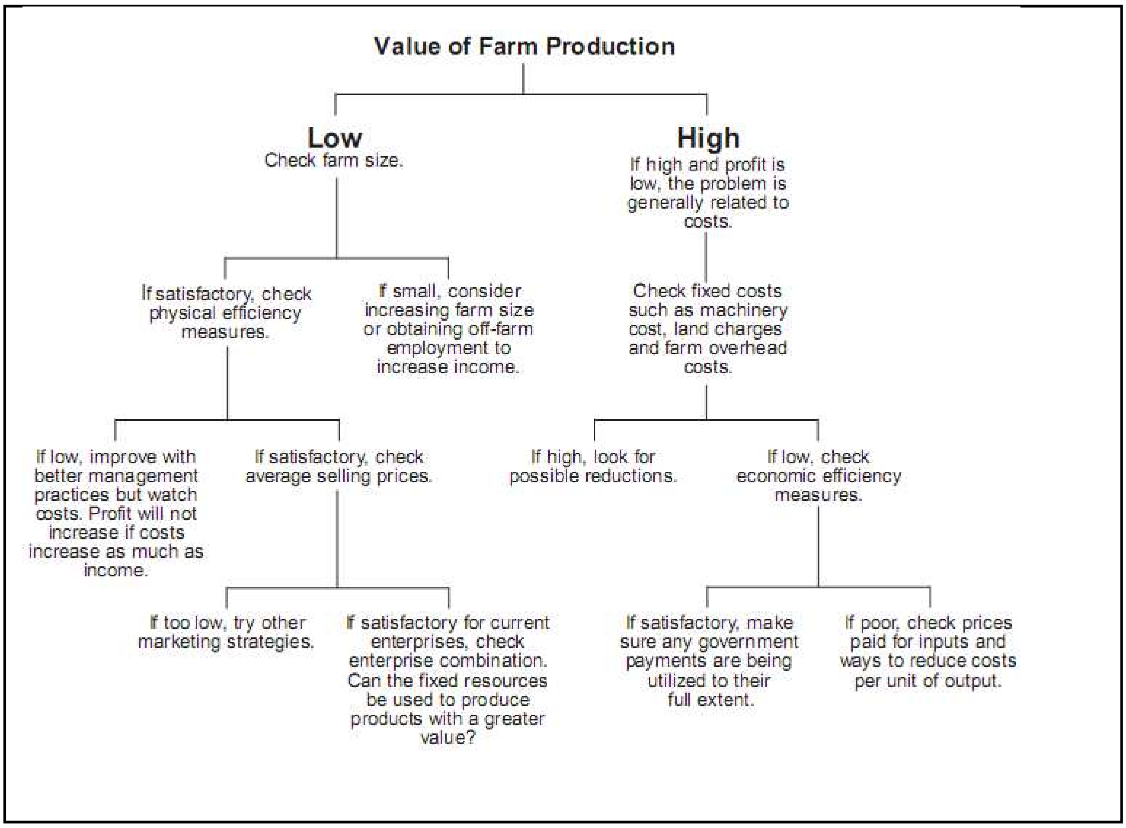



Figure 2.6 Procedure for diagnosing a farm profitability problem
Source: Stiles et al. (2007)

## 2.6 Management Frameworks

### 2.6.1 PDCR process

The plan-do-check-review process is a structured way of continually improving a process. It creates a cycle by which the consequences of decisions made and implemented can be checked and future decisions altered accordingly. Feedback from the indicators can be used to continually improve the sustainability of farming practices and to demonstrate the sustainability of farming practices to regulator authorities (MAF, 1997). A good decision making process involves feedback loop is the plan-do-check-review process as shown in Figure 2.7. Policy maker can apply this framework to the seasonal, annual and long term decision required for irrigation.

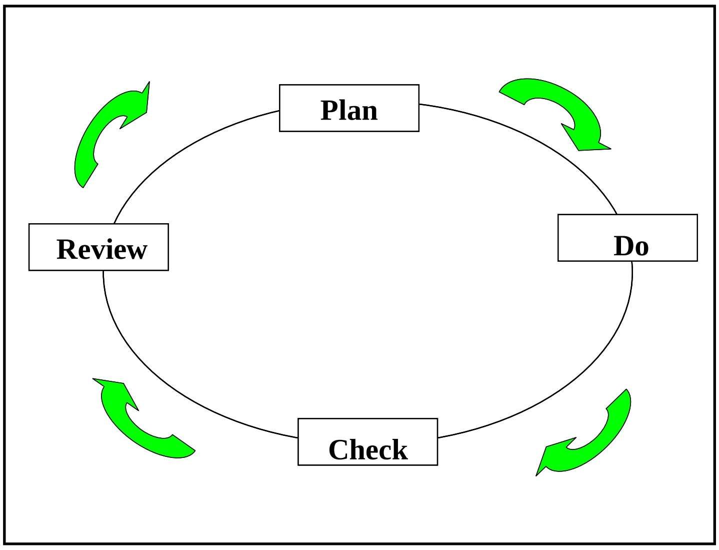



Figure 2.7 The Plan-Do- Check- Review process
Source: MAF (1997)

### 2.6.2 DPSIR framework

Driving forces-Pressures-State-Impacts-Responses (DPSIR) framework is useful in describing the relationships between the origins and consequences of environmental problems but in order to understand their dynamics it is also useful to focus on the links between DPSIR elements (EEA, 1999). According to the definitions of EEA, the driving forces (D) are the human activities causing an environmental problem. The pressures (P) regard to the level and source of pressure. The state (S) describes the extent of the current problem e.g. amount of soil erosion and soil contamination. The impacts (I) refer to the effects of the problem on creating further problems e.g. land productivity loss and biodiversity loss. The responses (R) are the strategies to solve or minimize the problems. The DPSIR framework is shown in Figure 2.8.

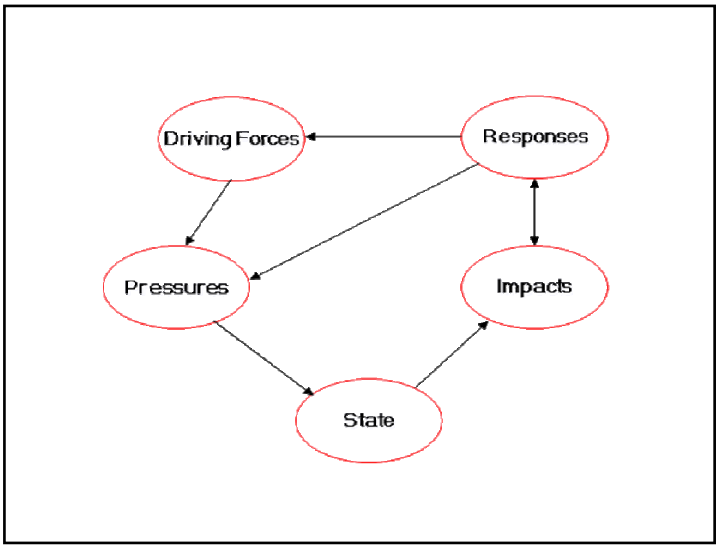



Figure 2.8 The DPSIR framework
Source: EEA (1999)

### 2.6.2.1 Application of DPSIR framework

The agricultural DPSIR model is the analytical framework which used to identify the agri-environmental indicators. It is adopted in the Commission Communication COM (2002) and derived from the DPSIR framework developed by EEA (Pisano, 2002). The agricultural DPSIR model is a partial model which is meant to capture the key factor intervening in the relationships between agriculture and the environment and to reflect the complex chain of causes and effects between these factors as shown in Figure 2.9.

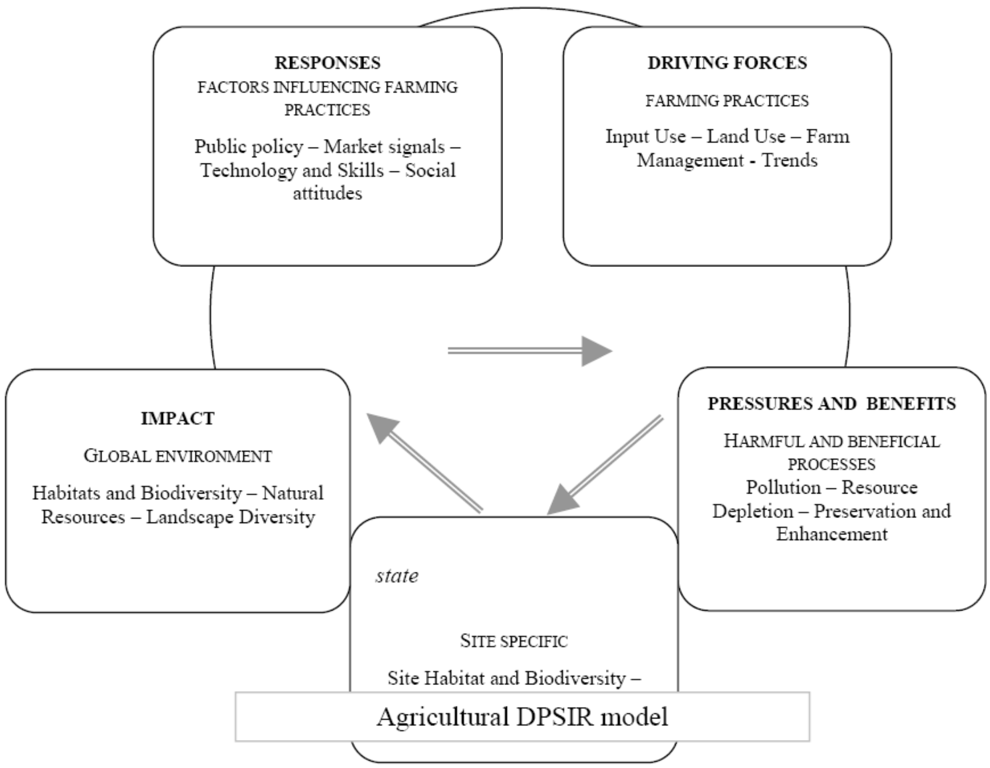



Figure 2.9 The agricultural DPSIR model
Source: Pisano (2002)

The Driving forces, Pressure, State, Impacts and Responses framework has been basically widely adopted to describe relationships between human activities and environment. Pressure, State and Impact components reflect the physical part of the framework, Driving forces and Responses are more deeply linked to human resources. The first one being related to the decision taken on how to carry out a productive process and the second one to the reaction from consumer, producer and other actors of the agri-food chain (for agriculture sector) and moreover to the new public policy, to the financial instrument and to market responses. The DPSIR framework for agricultural activity is presented in Figure 2.10.

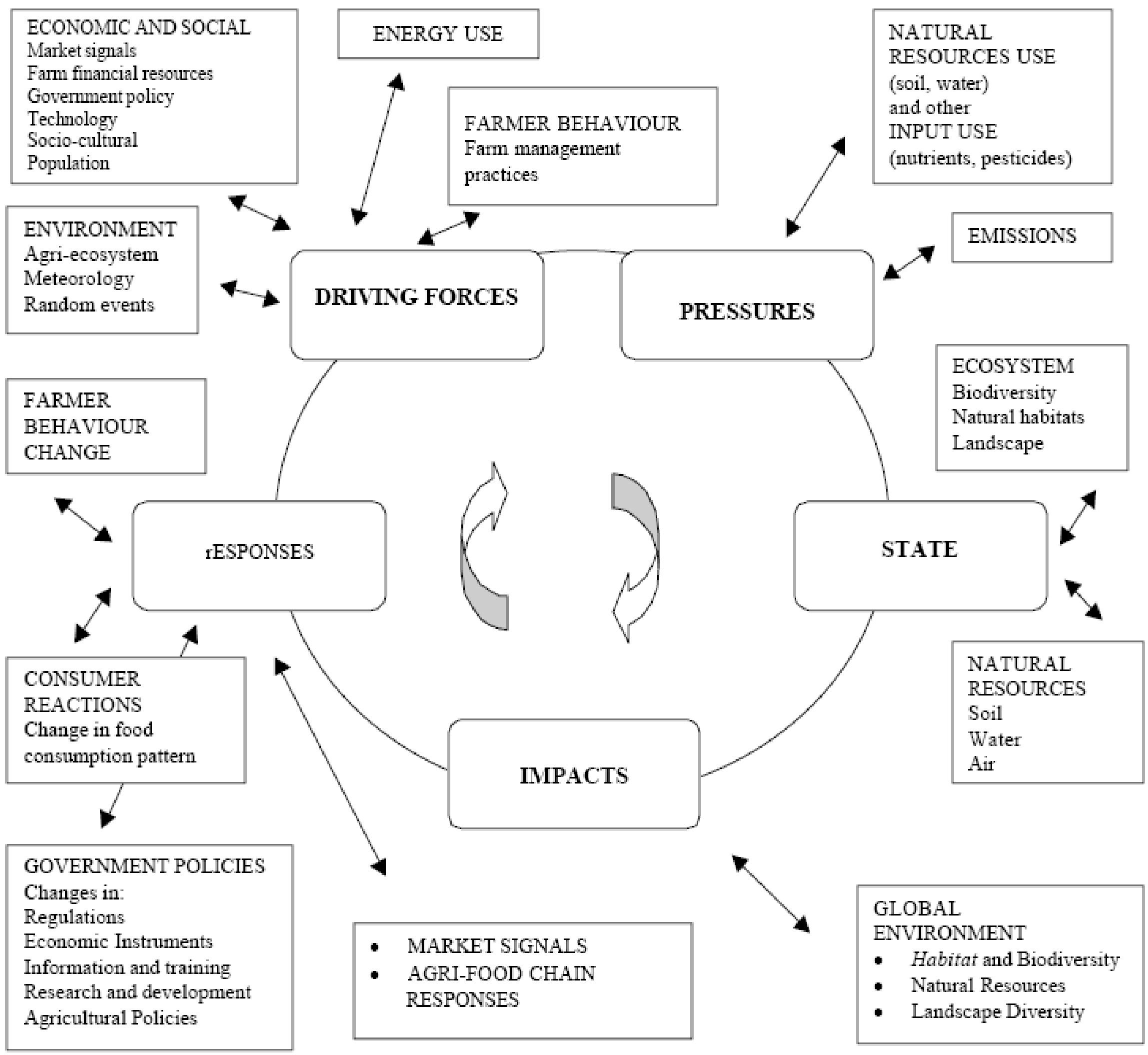



Figure 2.10 The DPSIR framework for agricultural activity
Source: ISTAT (2001)

A similar approach is proposed for assigning agricultural sustainability. The widely accepted DPSIR framework is used to identify causal chains. The DPSIR framework is used to assemble a list of indicators based on their categories and the cause effect relationships. The driving force indicators in the proposed framework define the context of agricultural production systems. The pressure indicators define stress on the system as characterized by trends in major multidimensional attributes of agricultural sustainability (productivity, stability, reliability, resilience and adaptability). The state and impact indicators determine the vulnerability of the agro ecosystem and are characterized by respective environmental and socio-economic impacts indicators. The response indicators define policy instruments, management and institutional strategies adopted for ensuring sustainability of agro economic system in the long run (Rao and Rogers, 2006). The variables that characterize each indicator are presented in Figure 2.11.

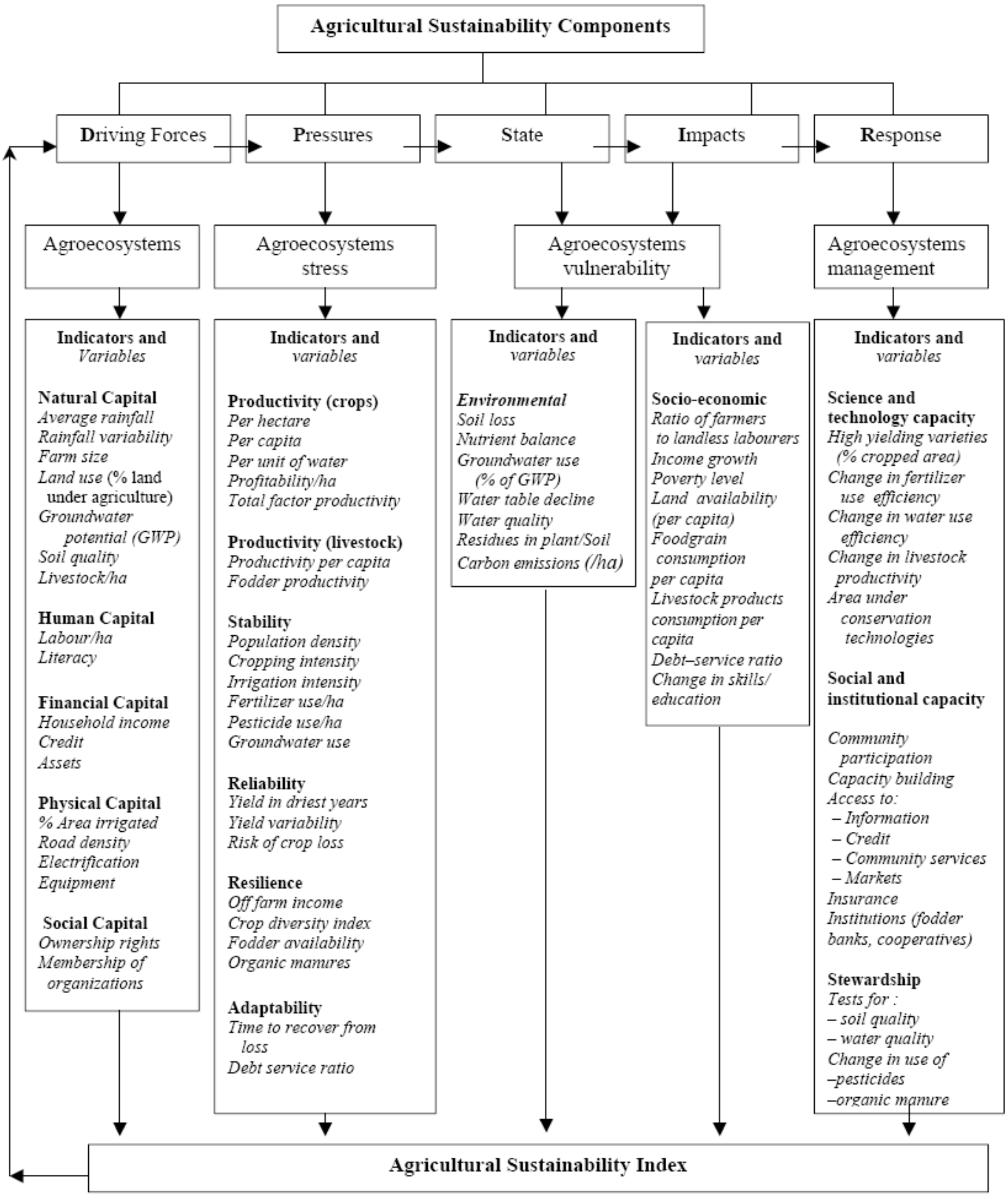



Figure 2.11 Agriculture sustainability assessment framework
Source: Rao and Rogers (2006)

# Chapter 3
# Research Methodology

The methodology consists of research design of the study, selection and description of the study area, data collection including primary and secondary data and then statistical analysis such as determination of dominant factors affecting irrigation system and determination of dominant irrigation sustainability index using principal component analysis.

## 3.1 Research Design

Research design provides information on how the study will be conducted. This information is needed to prepare the direction and coverage of the study. A research design of the study is shown in Figure 3.1. A detailed description of the coordination scheme is given in Table 3.1.

Table 3.1 Coordination Scheme

| Objective | Component | Possible Data Sources | Data Analysis |
|---|---|---|---|
| 1. To identify factors affecting the management of irrigation system in selected projects of Tha Chin Basin. | -Physical<br>-Socio economic<br>-Environmental<br>-Institutional | -Field survey<br>-RID, MTD<br>-LDD | Data analysis from questionnaires, report and field survey using PCA |
| 2. To develop a methodology for generating an irrigation sustainability index based on key indicators. | -Physical<br>-Socio economic<br>-Environmental<br>-Institutional | -Field survey<br>-RID, MTD<br>-LDD | Data integration and analysis using PCA |
| 3 To assess the sustainability of irrigated areas in selected projects of Tha Chin Basin based on ISI. | Generating sustainability map using GIS | | |
| 4. To formulate management strategies for sustainable irrigation management based on a modified DPSIR framework. | -Policy<br>-Technique<br>-Institution<br>-Management | -Decision maker<br>-Publish<br>-Report | Data analysis from ISI and modified DPSIR framework |

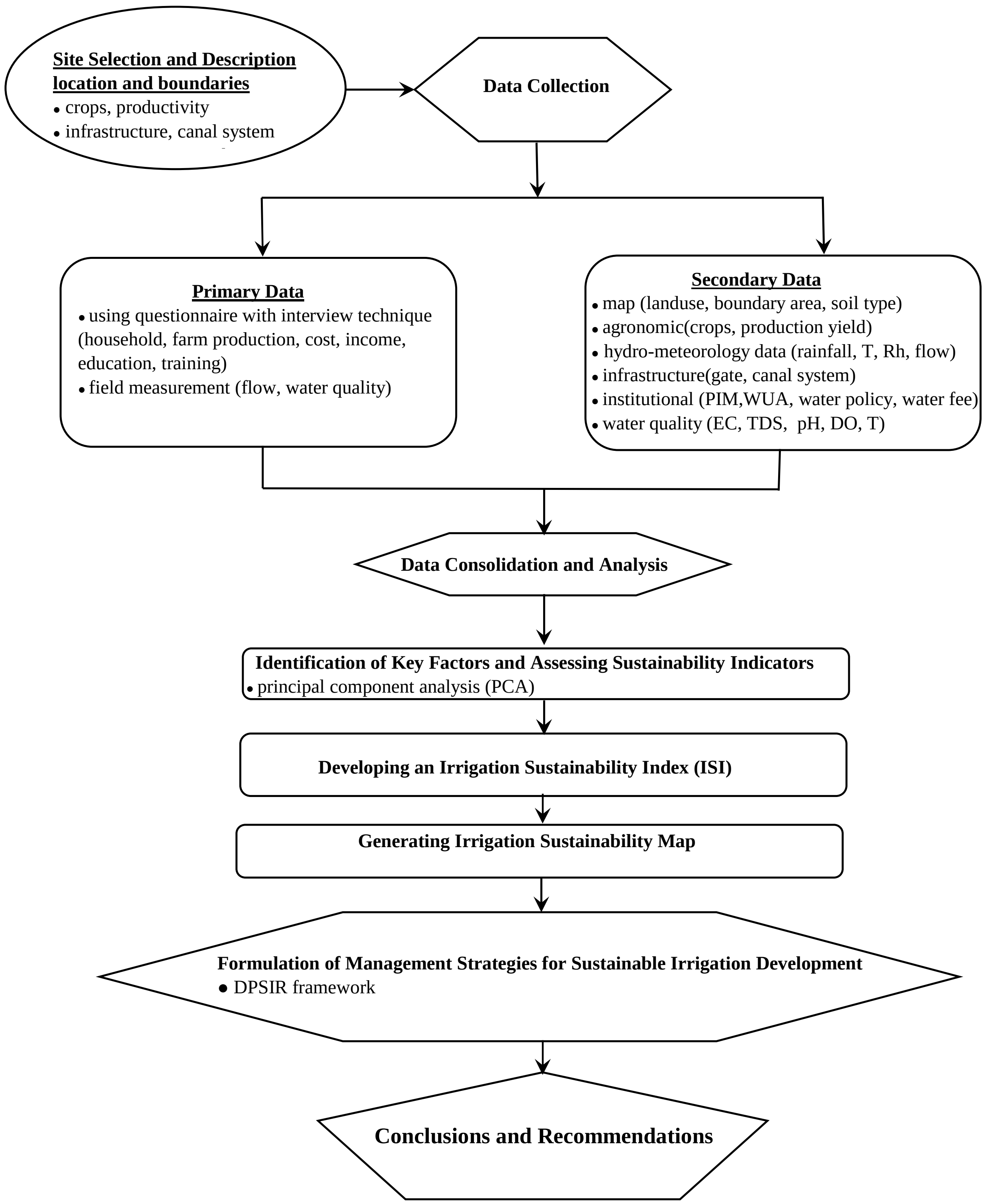



Figure 3.1 Research design

## 3.2 Selection and Description of Study Area

### 3.2.1 Selection of study area

Tha Chin Basin was selected as study area based on the report, "The Master Plan for Development of Water Resources and Rehabilitation of the Existing Irrigation Project for the 9th National Economic and Social Development Plan"(RID, 2003). The outcome of report showed that four basins need to attract further studies. The process of integrated water resource development and planning, Yom Basin is considered to be the critical basin in the North region. Tha Chin Basin is considered to be the critical basin in the Central region, Chi Basin is considered to be the critical basin in the Northeast region and Eastern Seaboard Basin is considered to be the critical basin in the South region. This report covered a detailed analysis of all 25 basins in terms of the supply potential and water demand. Moreover, Tha Chin Basin is a rice production area. Despite its being Thailand's economic crop, this area showed low production efficiency. Other problems identified in this basin were:

- Diversion of water from Mae Klong basin to Tha Chin Basin has decreased.
- Water quality is a serious problem on the lower part.

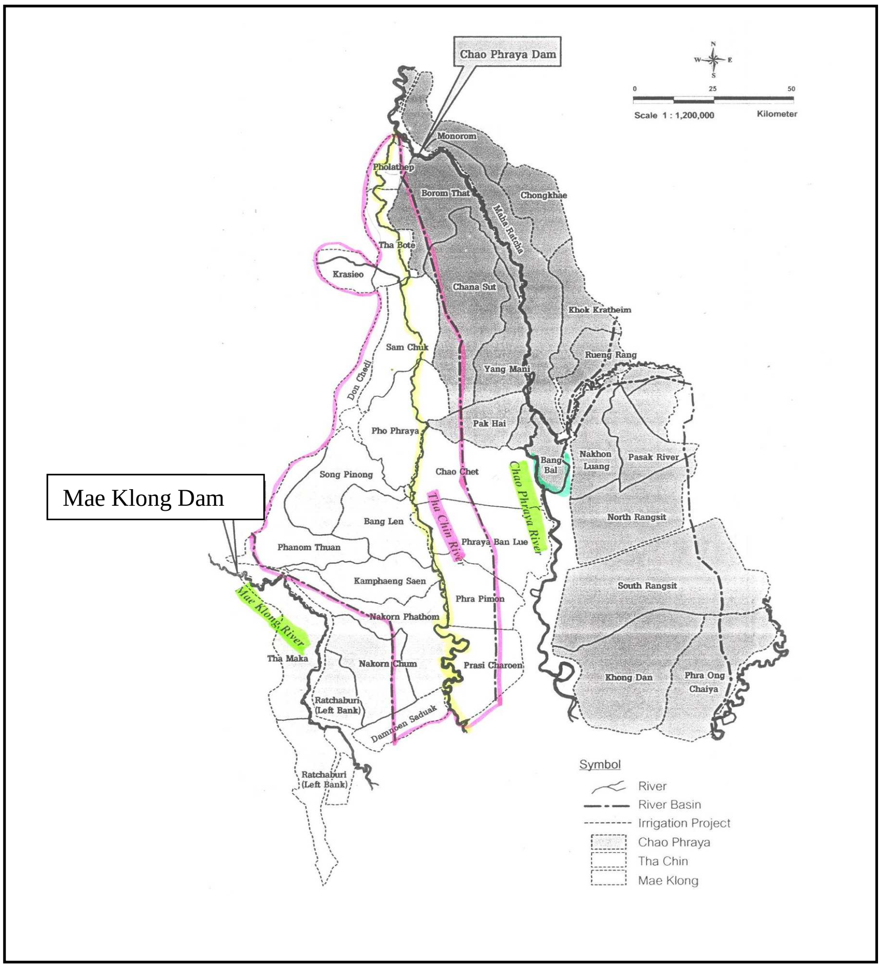



Figure 3.2 O&M project of Chao Praya, Tha Chin and Mae Klong River
Source: Vongvisessomjai (2006)

Figure 3.2 shows the location of existing Operation and Maintenance (O&M) Projects within Tha Chin Basin namely: Thabote, Krasieo, Samchuk, Donjedee, Phophraya, Songpinong, Banglen and Kamphaengsaen. O&M project is an individual administration project under the Regional Irrigation Office (RIO) and under the administration of the Royal Irrigation Department (RID). Thabote, Samchuk, Donjedee and Phophraya O&M project get their irrigation water from Chao Phraya dam whereas Songpinong, Banglen and Kamphaengsaen O&M project get their irrigation supply of water from Mae Klong dam. Table 3.2 shows the name and irrigation area of O&M projects in Tha Chin Basin.

In this study, Kamphaengsaen O&M project (KPP) and Phophraya O&M project (PPP) were selected as study areas based on their location and crops. Figure 3.3 shows the location of O&M projects in Tha Chin Basin and selected projects. KPP and PPP are the first project being a part of development of Mae Klong basin and Suphanburi river basin respectively. Irrigation systems of KPP and PPP projects are 32 and 75 years old. KPP is a rice and sugarcane production areas. There are water management conflicts for rice and upland crops. Some area has land consolidation. Moreover, some area use pump for diversion of water to the field. PPP, where rice is mainly produced, is located in the middle part of Tha Chin Basin and there had been problems in rainy season. For instance, some part of the irrigated areas (zone) get irrigation water from the drainage system such as the lower part of water allocation in section one.

Table 3.2 Name and Irrigation Area of O&M Projects in Tha Chin Basin

| No. | Regional Irrigation Office (RIO) | Operation and Maintenance Project | Location (Province) | Irrigation Area (Rai[*a]) |
|---|---|---|---|---|
| 1 | 11 | Choachet-Bangyihon | Ayutthaya | 162,400 |
| 2 | 11 | Phrayabanlu | Nonthaburi | 175,200 |
| 3 | 11 | Phrapimon | Nakonphatom | 133,000 |
| 4 | 11 | Phasicharoen | Nakonphatom | 80,000 |
| 5 | 12 | Polathep | Chainat | 96300 |
| 6 | 12 | Thabote[*b] | Chainat | 196,356 |
| 7 | 12 | Boromthat | Chainat | 365,000 |
| 8 | 12 | Krasieo[*b] | Supanburi | 130,000 |
| 9 | 12 | Samchuk[*b] | Supanburi | 305,000 |
| 10 | 12 | Donjedee[*b] | Supanburi | 133,000 |
| 11 | 12 | Phophraya[*b] | Supanburi | 370,000 |
| 12 | 12 | Chanasute | Singburi | 475,000 |
| 13 | 12 | Pakhai | Ayutthaya | 206,000 |
| 14 | 13 | Phanomthuan | Kanchanaburi | 48,660 |
| 15 | 13 | Songpinong[*b] | Suphanburi | 311,750 |
| 16 | 13 | Banglen[*b] | Nakonphatom | 353,200 |
| 17 | 13 | Kamphaengsaen[*b] | Kanchanaburi | 252,800 |
| 18 | 13 | Nakonpatom | Kanchanaburi | 182,100 |
| 19 | 13 | Nakhonchum | Kanchanaburi | 265,000 |
| 20 | 13 | Damnoensaduak | Rachaburi | 126,000 |

Source: RID (2003)

Note: 6.25Rai[*a] = 1 hectare

[*b] =Operation and Maintenance Project within Tha Chin Basin

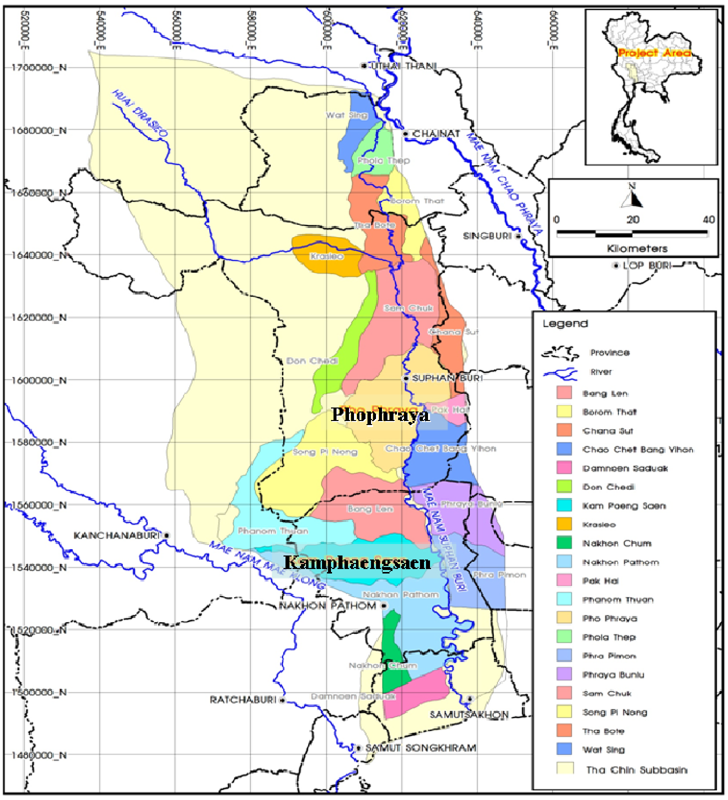



Figure 3.3 Operation and maintenance projects in Tha Chin Basin

The main problems based on field survey from two projects are listed as follows:

1) Insufficient of RID staffs
2) Upstream farmers divert water to their field ignoring schedule planning
3) Water fee was not charged
4) Water users group are not strengthened.
5) Lack of coordination between Operation and Maintenance Project and Tambon Administrative Office.
6) Lack of cooperation among farmers
7) Water user leader do not take strong action
8) Water demand calculated by RID office and O&M Project do not match.
9) Water is pumped out of the field to the irrigation canal
10) Gate operation problems
    10.1) The operation does not follow the policies
    10.2) Lack of gate discharge calibration
11) Funding problem for operation and maintenance
12) Illegal pumping from canal

### 3.3 Data Collection

Primary and secondary data were obtained from various sources. Primary data were collected using interviews, questionnaires and field measurements. Secondary data such as site description, canal system map, land use map, climatic data, etc. were taken from reports and publications. Based on the significant contribution of factors in irrigation system management as reported in literature, most of factors were considered in this study as shown in Table 3.3.

Table 3.3 Data Collection Related to Factors Affecting Irrigation System

| Category | Related factors | Sources |
|---|---|---|
| 1. Physical | 1.1 Climate conditions (rainfall, temperature, humidity )<br>1.2 Soil property (soil fertility)<br>1.3 Irrigation water supply<br>1.3.1 flow ratio<br>1.3.2 field application ratio<br>1.4 Topography (elevation)<br>1.5 Relative location of irrigated areas<br>1.51 location of Sub-main Canal in the field<br>1.5.2 relative position of irrigated area to water resource<br>1.6 Ditch and drainage ditch condition<br>1.7 Flooding frequency | MTD,KPP,PPP<br><br>LDD<br>KPP,PPP<br><br><br>USGS<br>Questionnaire<br>Questionnaire<br>Questionnaire |
| 2. Socio-economic | 2.1 House hold size<br>2.2 Age structure<br>2.3 Education level<br>2.4 Experience of farmer<br>2.5 Land tenure<br>2.6 Crop yield<br>2.7 Production cost<br>2.8 Farm income<br>2.9 B/C ratio<br>2.10 Water user conflict occurrence | Questionnaire |
| 3. Environmental | 3.1 Soil quality<br>3.1.1 soil pH<br>3.1.2 soil EC<br>3.2 Water quality<br>3.2.1 EC<br>3.2.2 TDS<br>3.2.3 pH<br>3.2.4 DO<br>3.3 Crop residue treatment method | field measurement<br><br><br>field measurement<br><br><br><br><br>Questionnaire |
| 4. Institutional | 4.1 Manpower (number of staff and work load of staff)<br>4.2 Degree of satisfaction on water delivery<br>4.2.1 cultivated areas survey by WUG before irrigation season<br>4.2.2 planning of water delivery schedule by RID staffs and WUG<br>4.2.3 meeting between Chief of WUG and WUG for schedule planning agreement<br>4.2.4 listen to the opinion of WUG listening RID staffs<br>4.2.5 announcement of the irrigation schedule to all WUG<br>4.2.6 accountability of timeliness and fairness of water distribution<br>4.3 Communication between farmer and RID staff | Report<br>Questionnaire<br><br><br><br><br><br><br>Questionnaire |

They are divided into four groups, namely physical, socio-economic, institutional and environmental categories. According to Becker (1997), these factor were selected based on the criteria: easy to measure, easy to document, easy to interpret, cost effective, representative, relevant to users and widely accepted. Other factors were not considered such as financial factor and groundwater degradation because it is difficult to separate total budget of O&M project into each zone and data is not available for groundwater degradation.

In order to cover the concept of sustainability of irrigation system, the steps of activity were:

(1) Review and select indicators based on sustainability concept which is easy to measure, easy to document, easy to interpret, cost effective, representative, relevant to users and widely accepted.

(2) Classify indicator into four group namely; physical, socio-economic, institutional and environmental categories for the study area. The irrigation sustainability indicators were selected as shown in Table 3.4.

Table 3.4 Selected Sustainability Indicators

| Categories | Indicators |
|---|---|
| Physical | Soil property (soil fertility) |
| | Flow ratio |
| | Field application ratio |
| | Flooding frequency |
| Socio-economic | Crop yield |
| | Farm income |
| | Net farm income |
| | Awareness on irrigation water use |
| | Water user conflict occurrence |
| Environmental | Soil property (EC, pH) |
| | Irrigation water quality (EC, pH) |
| | Perception of drained water quality |
| | Perception of soil quality |
| | Crop residue treatment method |
| Institutional | Satisfaction on adequacy of water distribution |
| | Matching of farm operations with RID water delivery |
| | Reliability of continuous flow |
| | Satisfaction on water delivery planning process |
| | Willingness to pay |

### 3.3.1 Primary data

The primary data were collected from different activities using questionnaires with interview technique and field measurement such as water quality, soil quality and flow measurement. A detailed description of the questionnaire is shown in Appendix C.

#### 3.3.1.1 Questionnaires

Questionnaires were prepared, pre-tested and revised in order to gather the necessary information. The structure of questionnaires cover general information, irrigation capacity, household characteristics, crop, financial, income, water distribution, conflict, institutional and environment. Sampling size was estimated using the Yemane equation (Yemane, 1967). The relationship between level of precision, sample size and population can be expressed as Equation 3.1.

$$n = \frac{N}{1 + N.e^2} \tag{3.1}$$

Where
n = the number of selected household samples
N= the number of household
e = level of precision

Table 3.5 Number of Respondents and Confidence Level in KPP

| Zone | No. of water users | No. of respondents | Confidence level (%) |
|---|---|---|---|
| 1 | 615 | 41 | 85 |
| 2 | 404 | 40 | 85 |
| 3 | 500 | 45 | 86 |
| 4 | 837 | 40 | 85 |
| 5 | 445 | 38 | 84 |
| 6 | 480 | 38 | 84 |
| 7 | 309 | 45 | 86 |
| 8 | 154 | 40 | 86 |
| 9 | 375 | 57 | 88 |
| 10 | 831 | 54 | 87 |
| 11 | 663 | 60 | 88 |
| 12 | 519 | 74 | 89 |
| 13 | 553 | 50 | 87 |
| 14 | 341 | 23 | 80 |
| 15 | 803 | 30 | 82 |
| 16 | 380 | 73 | 89 |
| 17 | 314 | 63 | 89 |
| 18 | 661 | 75 | 89 |
| 19 | 758 | 45 | 86 |
| 20 | 464 | 68 | 89 |
| 21 | 822 | 49 | 86 |
| 22 | 602 | 53 | 87 |
| 23 | 744 | 47 | 86 |
| 24 | 666 | 60 | 88 |
| 25 | 495 | 58 | 88 |
| 26 | 291 | 60 | 88 |
| 27 | 199 | 70 | 90 |
| Total | 14,225 | 1,396 | 97 |

Table 3.5 and Table 3.6 show the number of water users and respondents and confidence level in KPP and PPP, respectively. According to Birchall (2010), a confidence levels of

95% is widely considered to be acceptable. Confidence levels of KPP and PPP are 97% and 96% respectively.

Table 3.6 Number of Respondents and Confidence Level at PPP

| Zone | No. of water users | No. of respondents | Confidence level (%) |
|---|---|---|---|
| 1 | 175 | 46 | 87 |
| 2 | 392 | 59 | 88 |
| 3 | 375 | 39 | 85 |
| 4 | 83 | 40 | 89 |
| 5 | 480 | 50 | 87 |
| 6 | 135 | 40 | 87 |
| 7 | 198 | 40 | 86 |
| 8 | 157 | 61 | 90 |
| 9 | 372 | 30 | 82 |
| 10 | 68 | 41 | 90 |
| 11 | 30 | 16 | 83 |
| Total | 2,465 | 462 | 96 |

### 3.3.1.2 Irrigation water quality

Irrigation water quality data were collected from two O&M projects. There are 44 and 22 water sampling stations in KPP and PPP, respectively. Three points were selected from each canal i.e. upper, middle and lower point. Water samples from canals were collected using the grab sample method at 0.3 m depth in the morning time (6.00-12.00). From each water sample, five indices were considered (i.e. pH, temperature (T), electric conductivity (EC), total dissolved solid (TDS) and dissolved oxygen (DO). Figure 3.4 and 3.5 show water sampling stations at both of KPP and PPP, respectively.

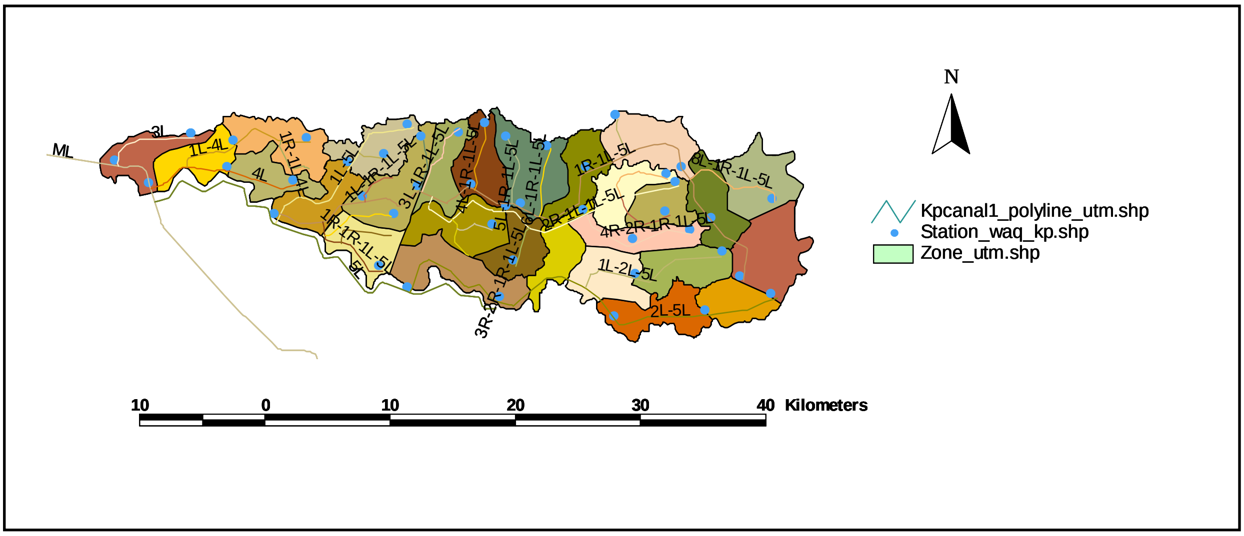



Figure 3.4 Water sampling stations at KPP

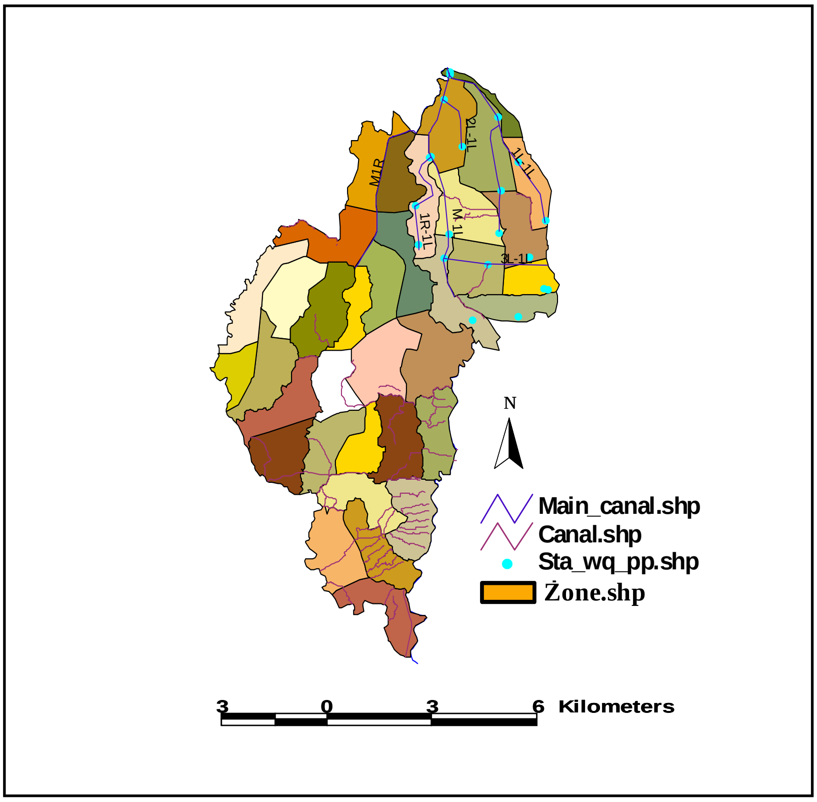



Figure 3.5 Water sampling stations at PPP

Data of irrigation water quality at KPP in wet season were collected on 8-9 August and 12-14 September, 2007 and dry season on 27-29 March and 29-30 May 2007. The average data of irrigation water quality were used for analysis as environment variable in wet and dry season as shown in Table A-1 and A-2 respectively.

Data of irrigation water quality at PPP in wet season were collected on 12 August and 16 September 2007 and dry season on 24 March and 5 May 2007. Average data of irrigation water quality were used for analysis as environment variable in wet and dry season as shown in Table A-3 and A-4 respectively.

To compare irrigation water quality using standard of irrigation water quality for agriculture as shown in Table A-5.

#### 3.3.1.3 Soil sampling

Soil data were collected from two O&M projects. There are 124 and 39 samples from KPP and PPP, respectively. Soil samples from the field were collected using a spade taken to a depth 15 cm and filled in the plastic bag. A separate soil sample was taken from each crop and area. It was ensured that each sample consisted of subsamples taken from at least five location within a garden (Vandre, 2006). In field that had been disked or levels, subsamples were collected randomly at each sampling site without regard to surface topography (Andrews et al., 2002). Large pieces of raw organic materials were removed from the soil surface before collecting the samples. Soil samples were analyzed for chemical properties at Regional Land Development Department Office. In this observation, nine indices were considered namely; pH, OM(%), N(%), P, K, Ca, Mg, cation exchange capacity (CEC) and base saturation (BS). Figure 3.6 and 3.7 show soil sampling stations at KPP and PPP, respectively. The values of parameters of soil at KPP and PPP are given in Table A-6 and A-7 respectively.

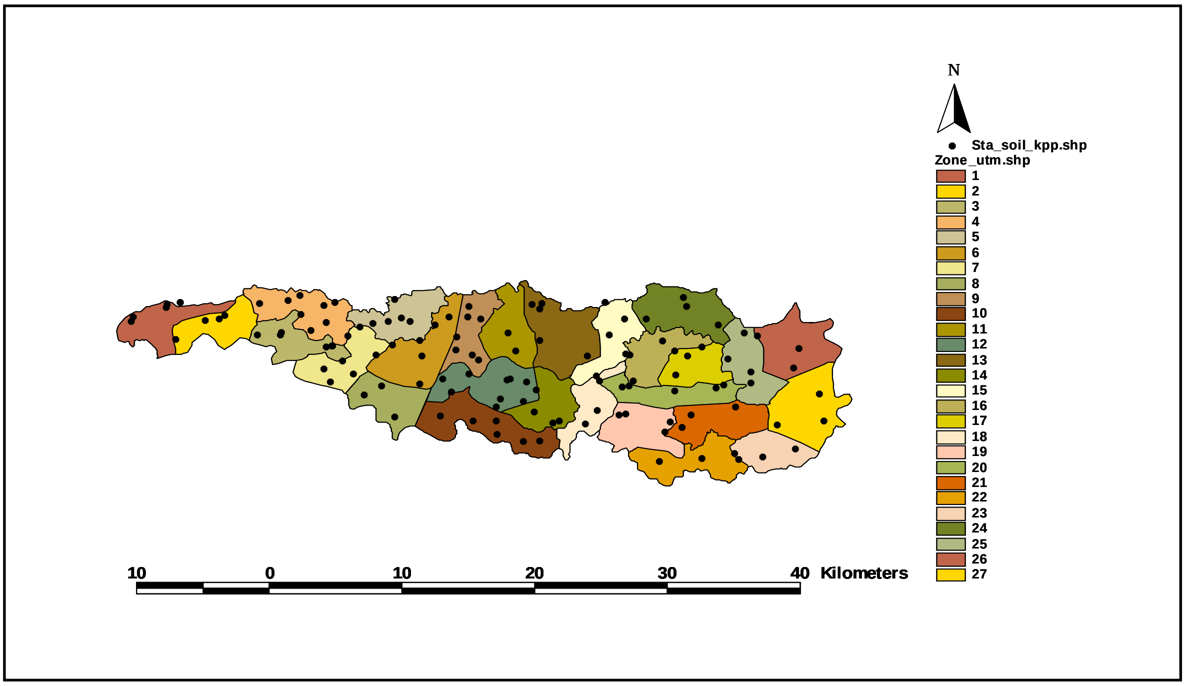



Figure 3.6 Soil sampling stations at KPP

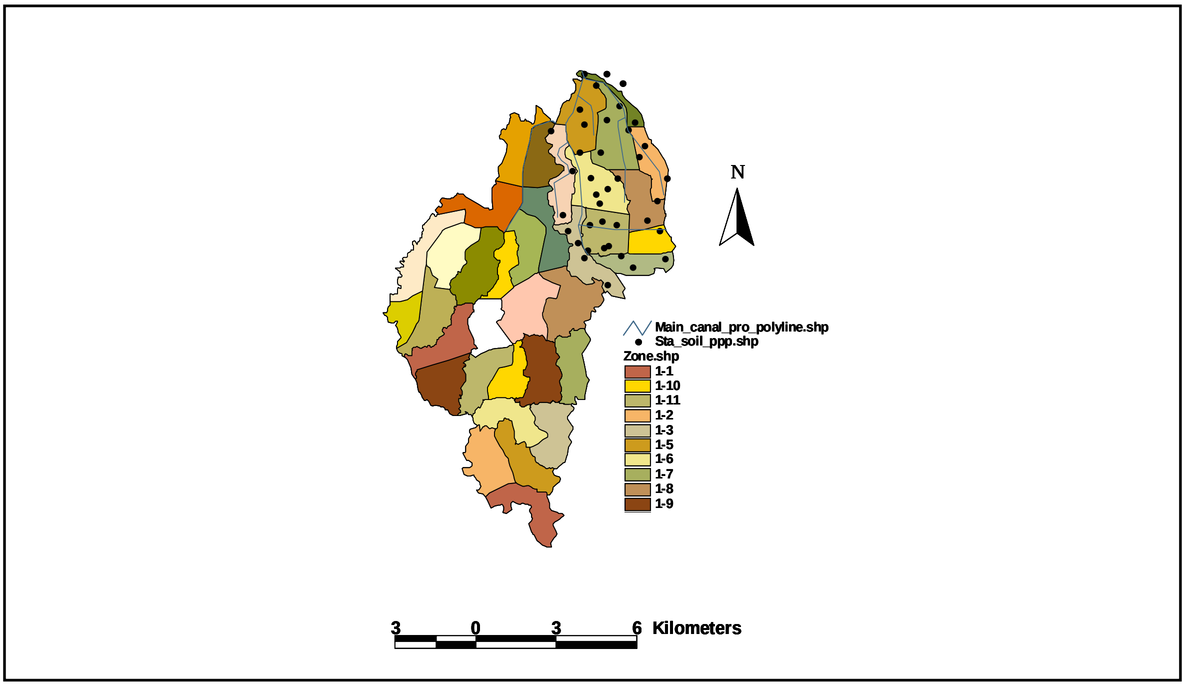



Figure 3.7 Soil sampling stations at PPP

### 3.3.2 Secondary data

The secondary data is related to physical, institutional, and environmental data in that it includes site description of KPP and PPP, climatic data (rainfall, temperature and relative humidity), digital elevation models and drained water quality. A detailed site description is provided as background information of operation and maintenance project.

#### 3.3.2.1 Site description

**a) Kamphaengsaen operation and maintenance project**

- **Location**

The project construction began in 1964 and was completed in 1975. It is the first project as part of development of Mae Klong basin. The Kamphaengsaen project is located in the Tha Chin Basin and receives water from the Mae Klong system as shown in Figure 3.8. It covers an area of 50,560 ha and the average annual rainfall is 980 mm, which stretches from latitude 13 $^{o}$ 54’ N to 14 $^{o}$ N and from longitude 99 $^{o}$ 48 ’ E to longitude 100 $^{o}$ 18 ’ E.

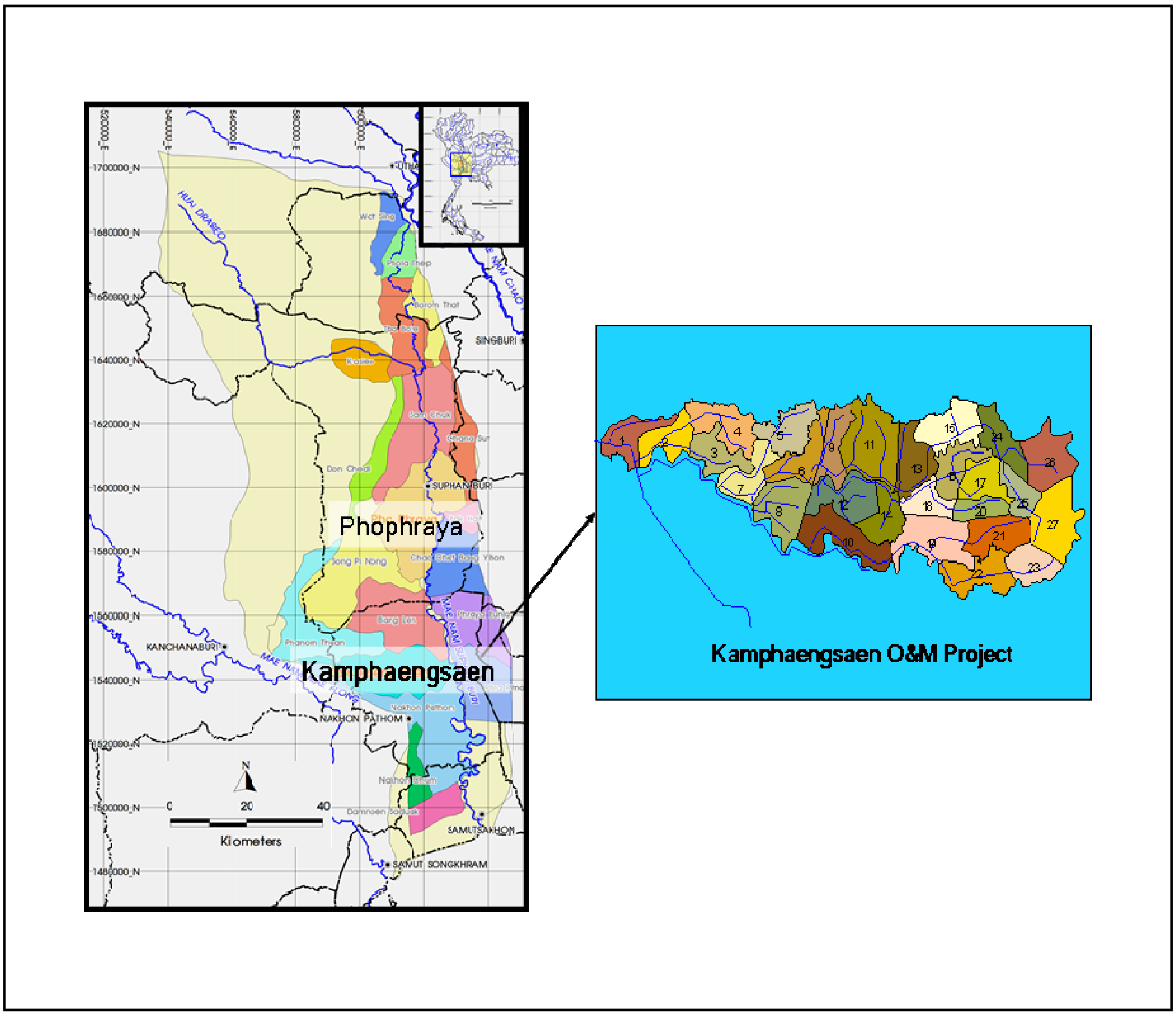



Figure 3.8 Location of KPP in Tha Chin Basin

- **Soil type**

Based on Land Develop Department classification, soil types are mostly clay which is suitable to rice production while other areas are suitable for vegetables and sugarcane. Figure 3.9 shows soil type map in KPP.

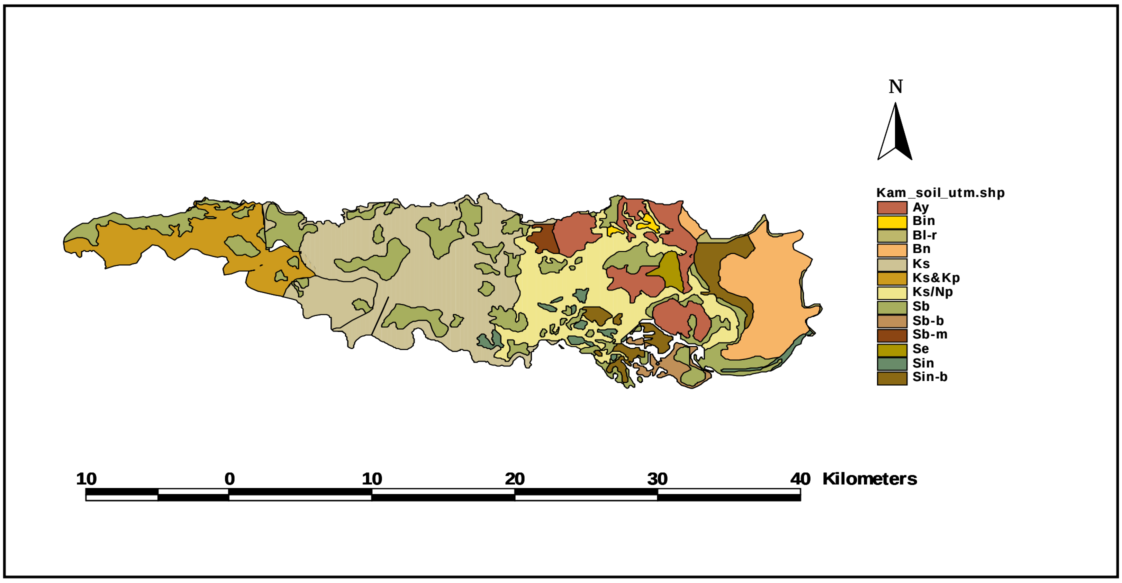



Figure 3.9 Soil type map of KPP

- **Land use**

The total land area covers 50,560 ha and irrigation area is 40,448 ha. Rice, sugarcane, farm crop, fruit tree, fish pond and shrimp farm total to 43%, 32%, 17%, 4.5% and 3.5% of the area respectively. Figure 3.10 shows the land use map in KPP.

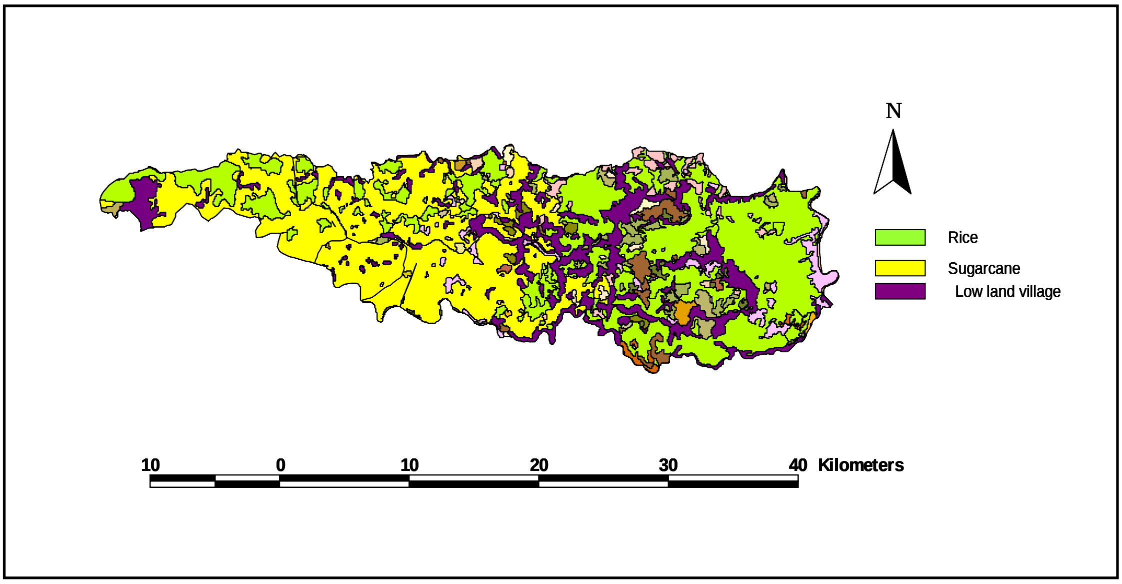



Figure 3.10 Land use map of KPP

- **Population**

There are 225,904 people living in the project area which is located in Kanchanaburi, Rachaburi and Nakhonphatom province. The breakdown of population by province is shown in Table 3.7.

Table 3.7 Population in KPP

| No. | Province | Population (person) |
|---|---|---|
| 1 | Kanchanaburi | 31,843 |
| 2 | Rachaburi | 12,010 |
| 3 | Nakhonphatom | 182,051 |
| Total | | 225,904 |

Source: (DOPA, 2005)

The main occupation of people is agriculture (production of rice, sugarcane, farm crop, shrimp farm and fish pond).

- **Administration**

The management of water in KPP is under the responsibility of the Regional Director, Regional Irrigation Office 13 of Royal Irrigation Department. KPP is divided into 1 branch and 4 sections as shown in Figure 3.11.

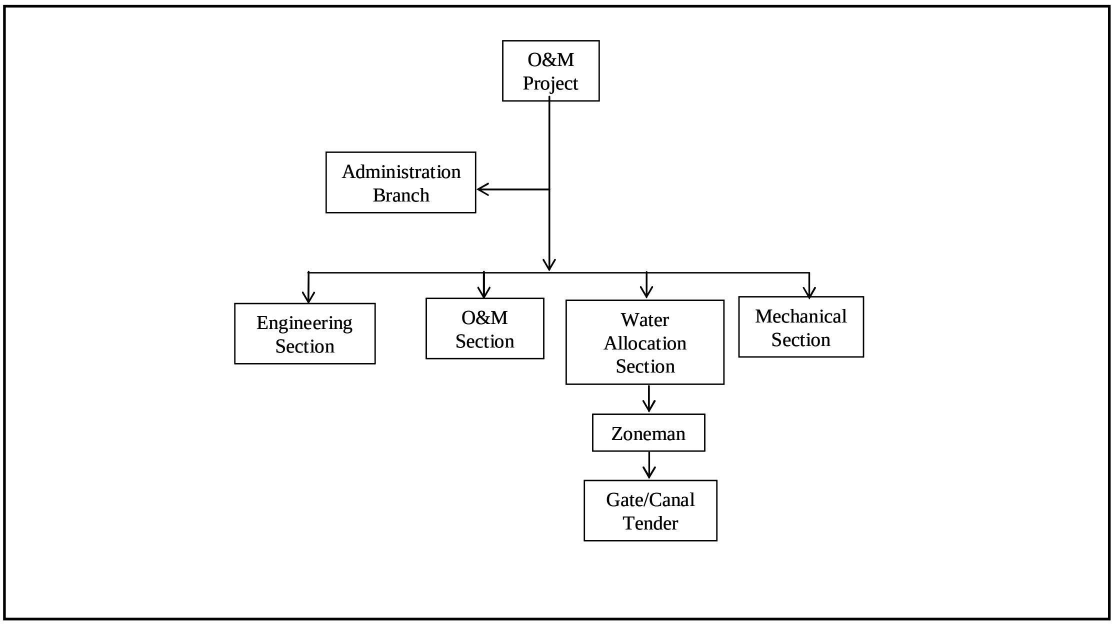



Figure 3.11 Organizational structure of KPP operation and maintenance project

The KPP has 3 water allocation sections as shown in Figure 3.12. Each water allocation section separates the irrigated area into zone boundary as shown in Figure 3.13. Each zone has field staff (zoneman) who takes care and contacts water user directly. There are 27 zones where average area of each zone is 1,873 ha.

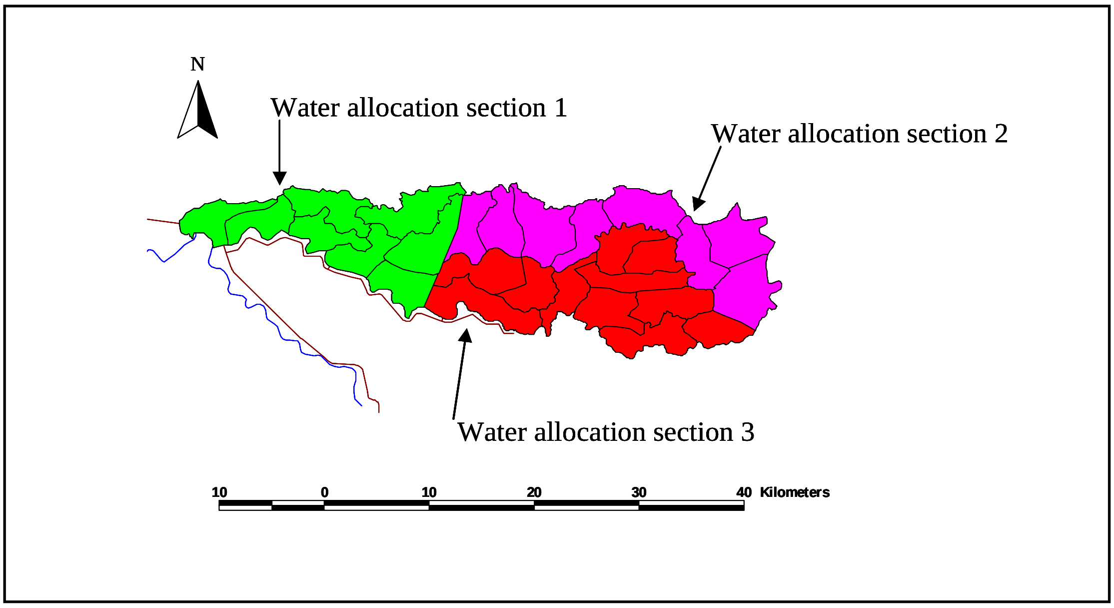



Figure 3.12  Water allocation section in KPP

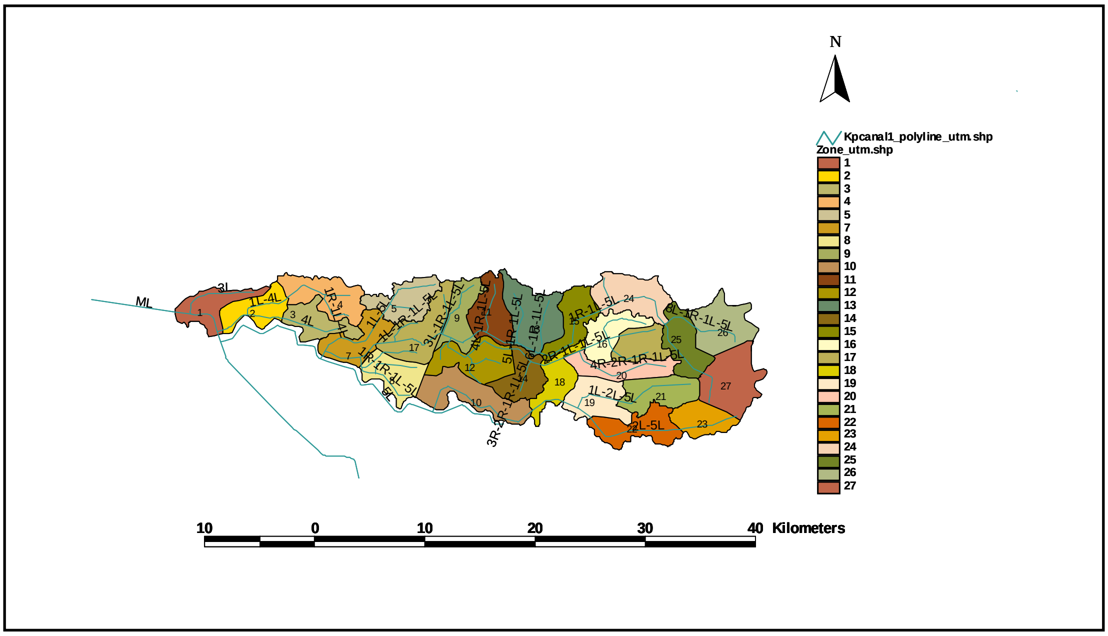



Figure 3.13  Irrigated area (Zone) in KPP

- **Canal system**

There are 29 canals consisting of main, secondary and tertiary canals with a total length of 258.74 km. Most of them are lined with concrete. The schematic diagram of canal system is illustrated in Figure 3.14 and a detailed description of canal system is shown in Figure 3.15.

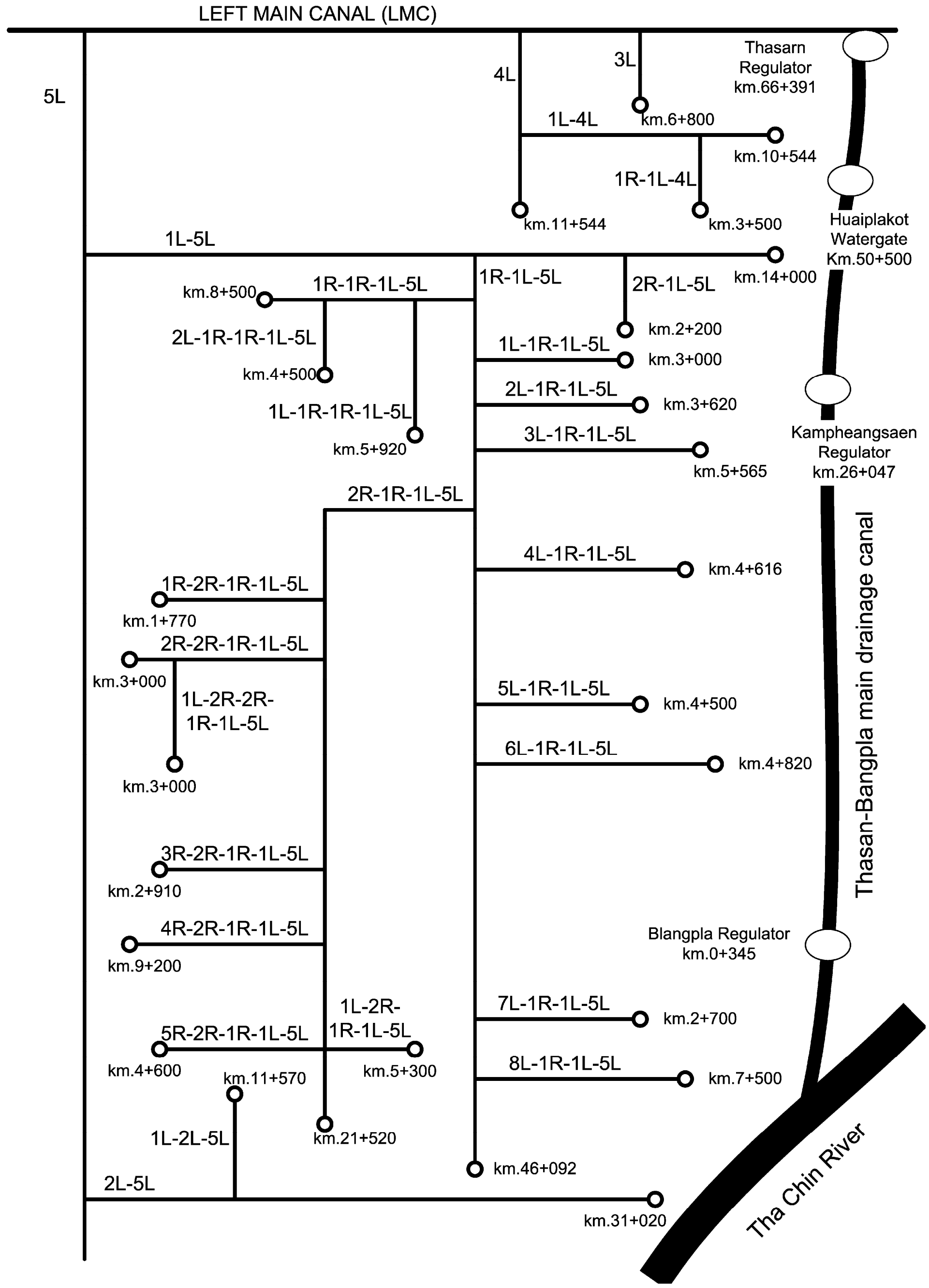



Figure 3.14 Schematic diagram of canal system in KPP

The water distribution system runs through the entire system by four canals namely:

1) Canal 3 L is secondary canal and has the total length of 6.8 km, supply water from main left bank canal at km 11+425.

2) Canal 4 L is secondary canal and has a total length of 11.54 km, water is supplied from the main left bank canal at km 14+443.

3) Canal 1L - 5L is secondary canal and has a total length of 14.625 km, water is supplied from the canal 5 L of Nakhon Phathom operation and maintenance project at km 11+584.

4) Canal 2 L – 5 L is secondary canal and has a total length of 32.14 km, water is supplied from the canal 5 L at km. 24+320.

The canal systems distribute water to the field through the main canal to secondary and tertiary canal. At the head of each canal, there is a farm turnout structure where the land area is supplied from farm turnout. The land area is grouped into a zone which is a service area.

Diversions of water to the irrigation areas are both due to gravity and pumping. Most areas in this project are of continuous water irrigation delivery.

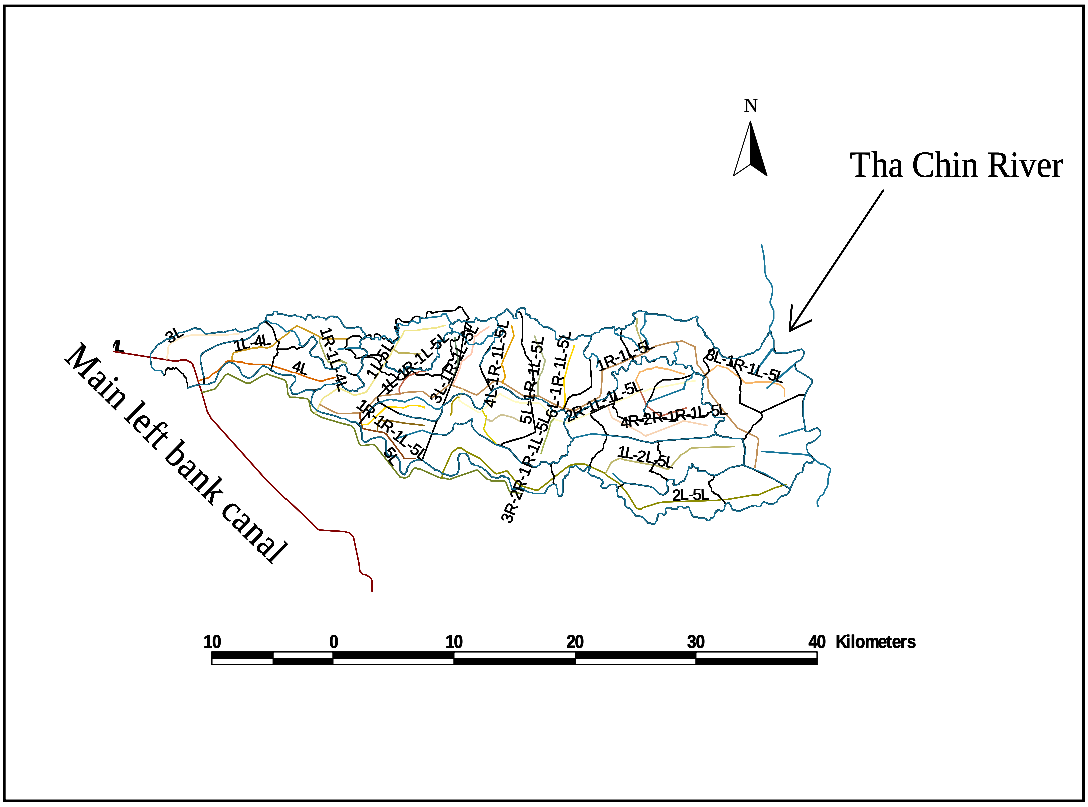



Figure 3.15 Canal system of KPP

- **Operation of KPP**

*Dry Season*; The operation system distributes irrigation water to the fields during 5 February to 4 June 2005 with 56.05 % efficiency in dry season.

*Wet Season*; The operation system distributes irrigation water to the fields during 3 December to 16 July 2005 with 52.03 % efficiency in wet season.

- **Cropping Patterns**

The main crops are rice, sugarcane, baby corn, and asparagus as shown in Figure 3.16. Rice fields are double cropped in KPP.

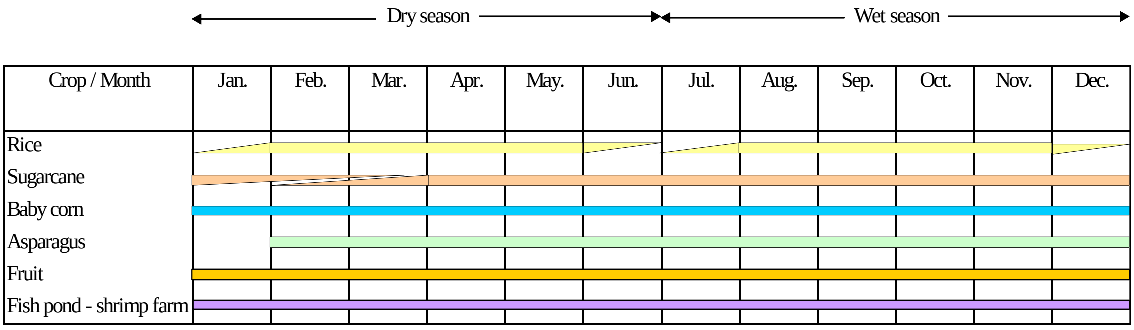



Figure 3.16  Crop calendars of KPP

## b) Phophraya operation and maintenance project

- **Location**

The project construction began in 1921 and was completed in 1932. It is the first project of development of Suphanburi river basin and the third project of Thailand. The Phophraya project is located in the Tha Chin Basin as shown in Figure 3.17 and receives water from the Chao Praya basin. It covers an area of 66,550 ha. It is located at latitude 14$^{o}$ 30' 80'' N and longitude 100$^{o}$ 07'06'' E.

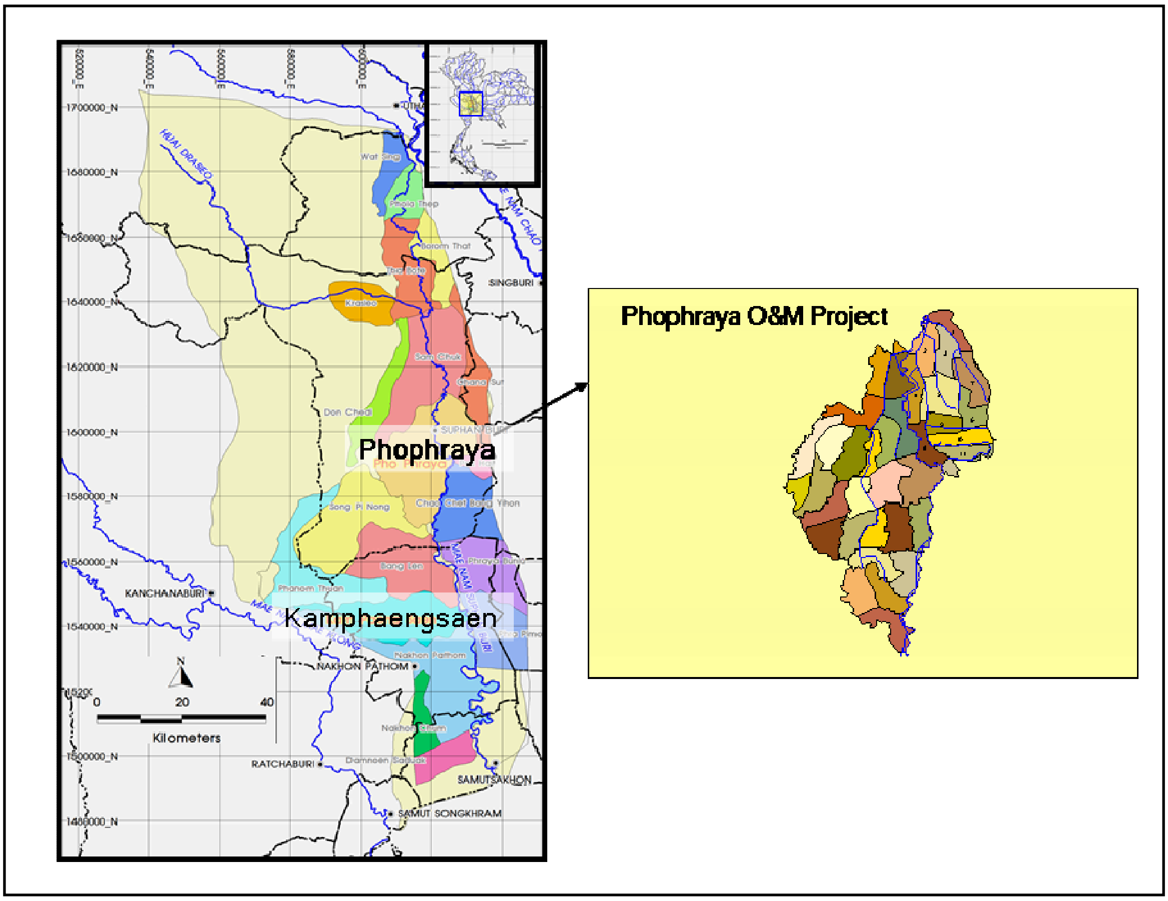



Figure 3.17  Location of PPP in Tha Chin Basin

- **Soil type**

According to Land Develop Department classification, most soil type is clay which is suitable for rice production. Soil type map in PPP is shown in Figure 3.18.

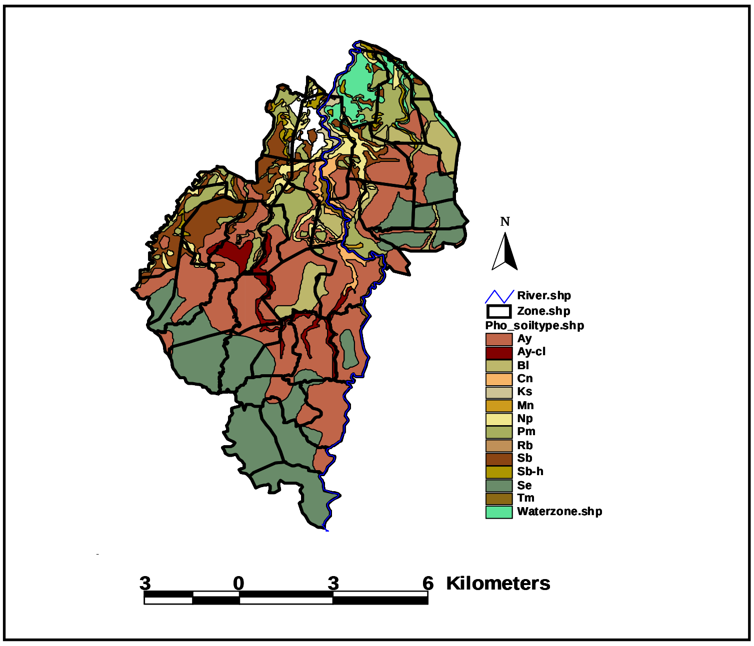



Figure 3.18 Soil type map in PPP

- **Land use**

The total land area covers 66,550 ha and irrigation area is 59,200 ha. Rice, fruit tree, fish pond, shrimp farm and farm crop are 90%, 5%, 4% and 1% of the area respectively. Figure 3.19 shows land use map in PPP.

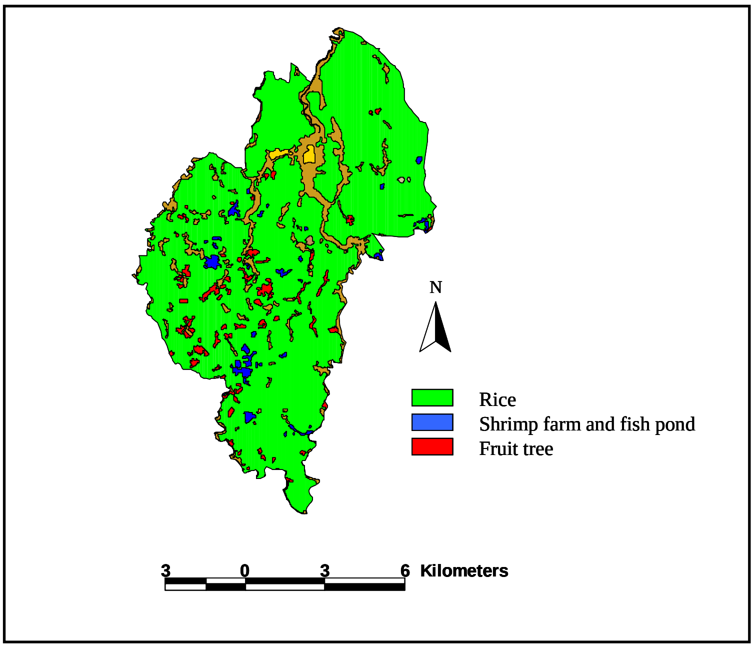



Figure 3.19 Land use map in PPP

- **Population**

There are 191,781 people living in the project area which is located in Suphanburi province. The breakdown of population by district is shown in Table 3.8.

Table 3.8 Population in PPP

| No. | District | Population (person) |
|---|---|---|
| 1 | Sriprajun | 8,148 |
| 2 | Muang | 114,632 |
| 3 | Bangplama | 50,469 |
| 4 | Songpinong | 18,532 |
| Total | | 191,781 |

Source: (Phophraya, 2003)

The main occupation of people is agriculture. Rice is the main crop in this project.

- **Administration**

The management of water in KPP is under the responsibility of the Regional Director, Regional Irrigation Office 12 of Royal Irrigation Department. This project is divided in to five administrative sections as shown in Figure 3.20.

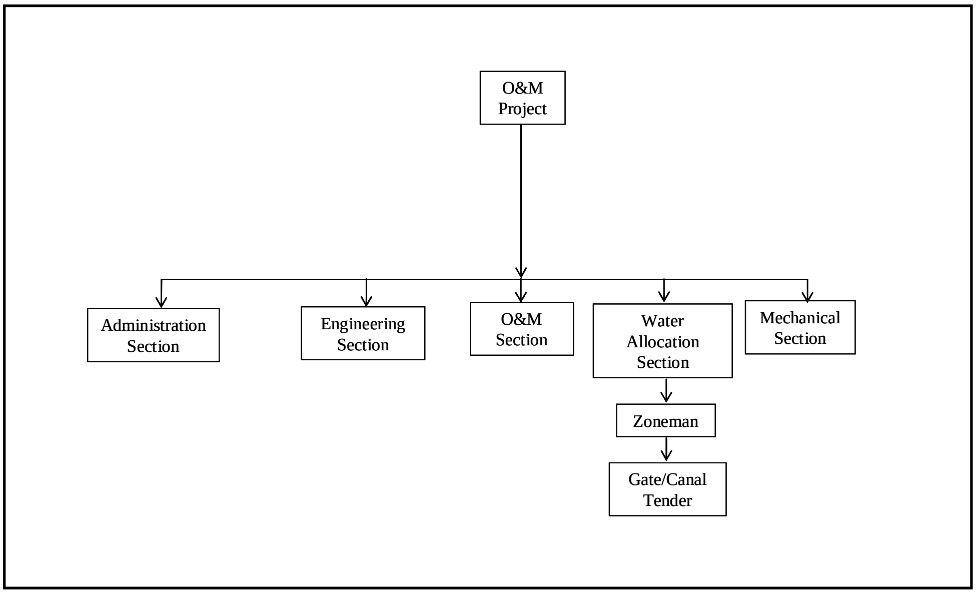



Figure 3.20 Organizational structure of PPP operation and maintenance project

This project is divided into four water allocation sections and there are 37 zones under water allocation sections. Each zone has an average area 1,799 ha and has field staff (zoneman) who takes care and contacts water user directly. Figure 3.21 and Figure 3.22 show water allocation section and irrigated area (zone) in PPP respectively.

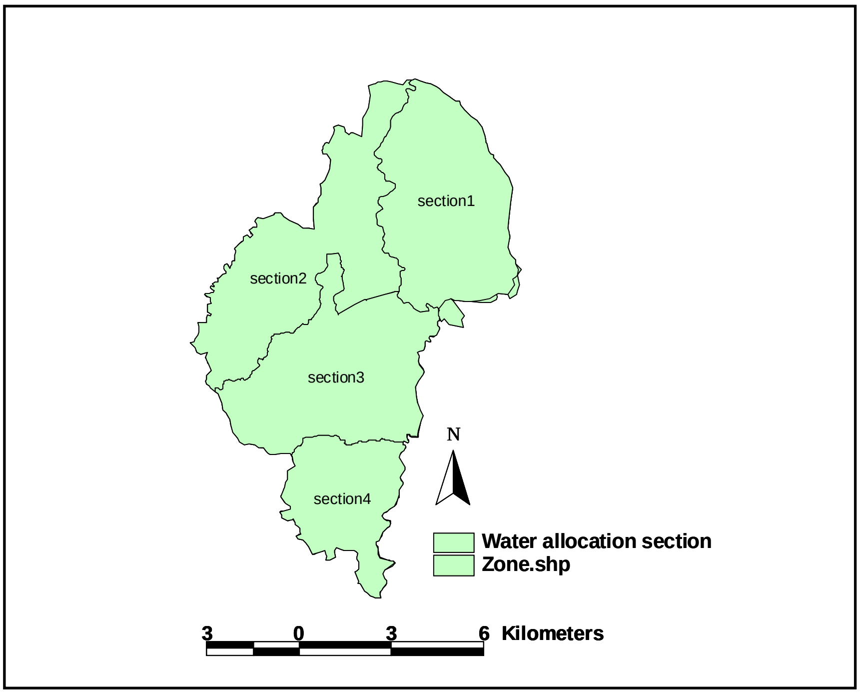



Figure 3.21  Water allocation section in PPP

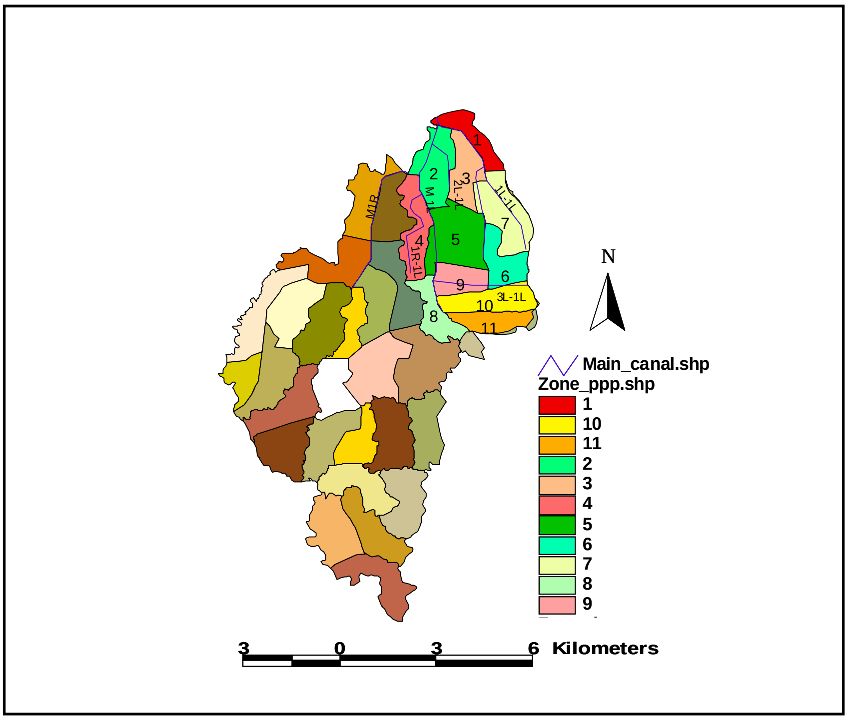



Figure 3.22  Irrigated area (Zone) in PPP

- **Canal system**

There are 17 canals consisting of main, secondary and tertiary canal with a total length of 219.6 km. the schematic diagram of canal system is illustrated in Figure 3.23 and a detailed description of canal system is shown in Figure 3.24. The water distribution system of Phophraya project starts from upper Chao Praya Dam at Polathep regulator through Tha Bote regulator and Samchuk regulator to Phophraya regulator at 117+000 km.

Diversions of water to the irrigation areas are due to gravity and pumping. There are two zones i.e. the downstream of zone 10 and zone 11 receiving water from drainage system.

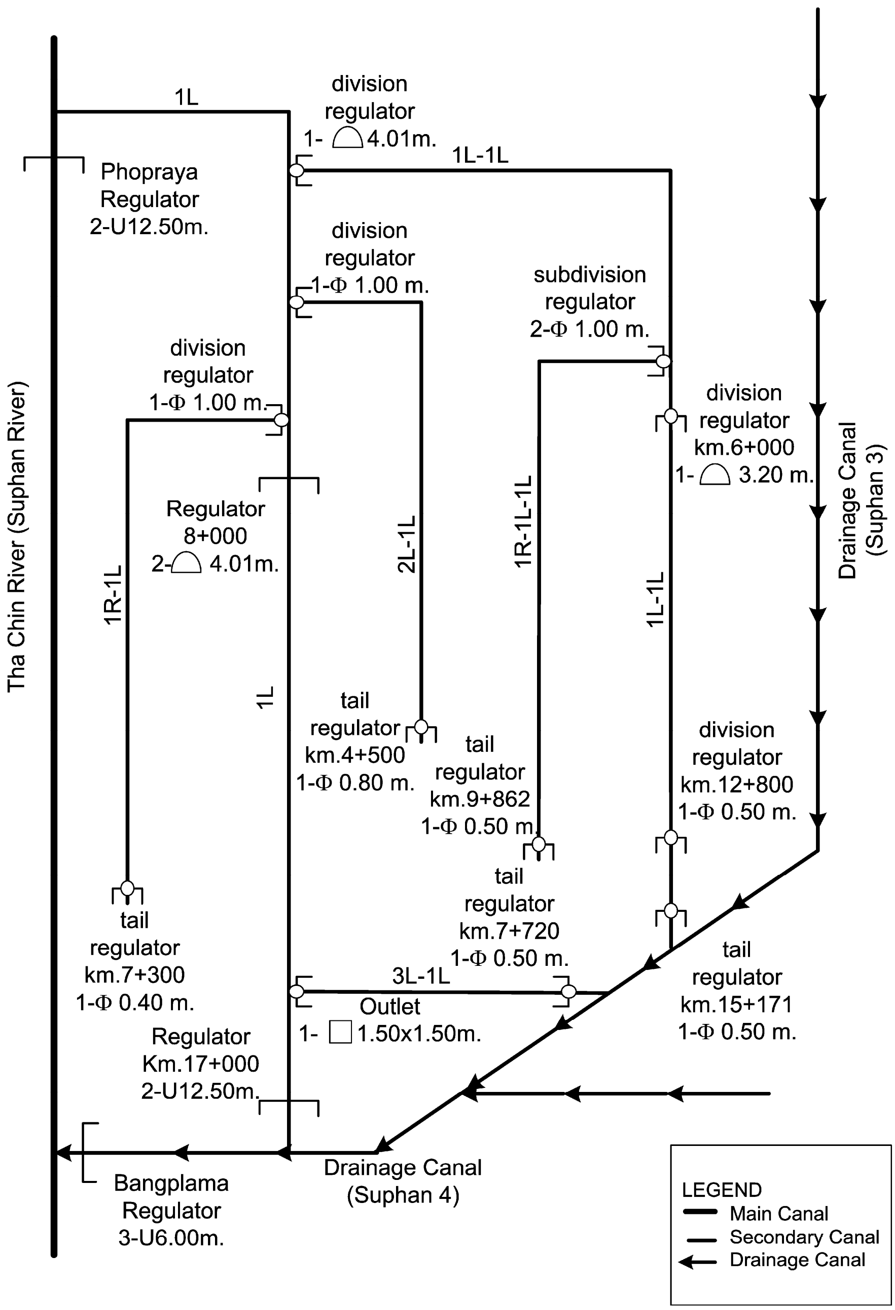



Figure 3.23 Schematic diagram of canal system in PPP

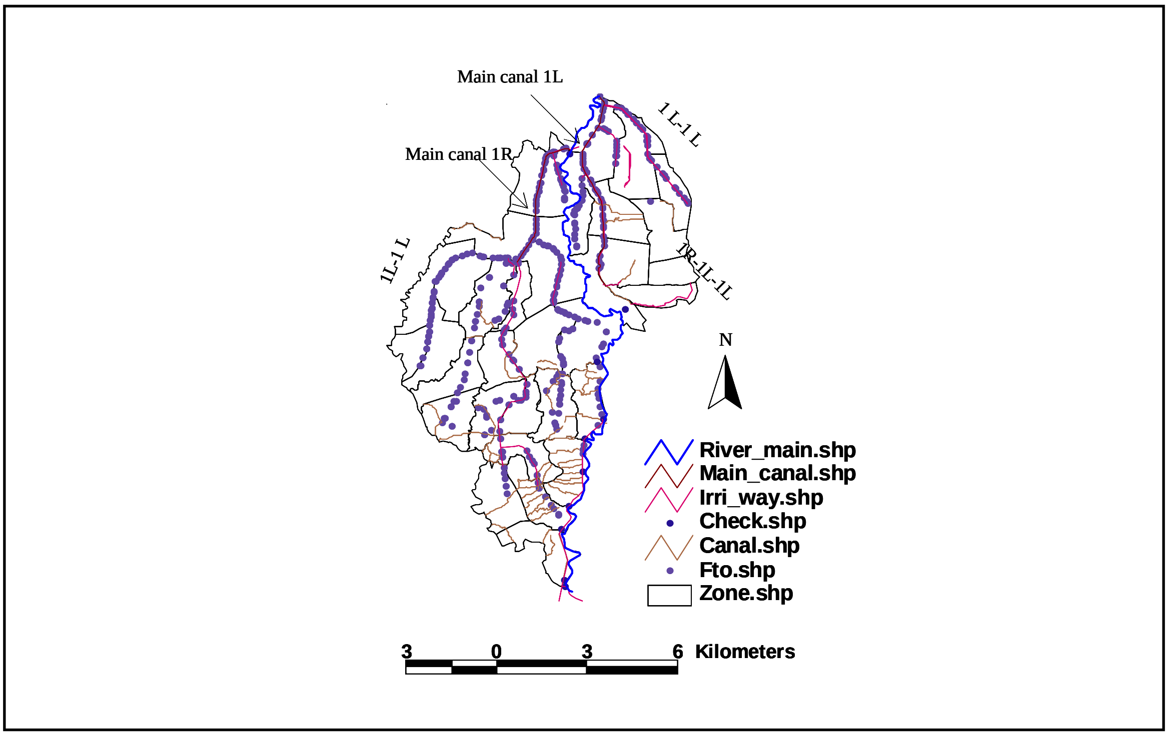



Figure 3.24 Canal system of PPP

- **Cropping patterns**

The main crops are rice, earth almond and sweet potato. Rice crop can be planted five times for two years. The crop calendar of PPP is shown in Figure 3.25.

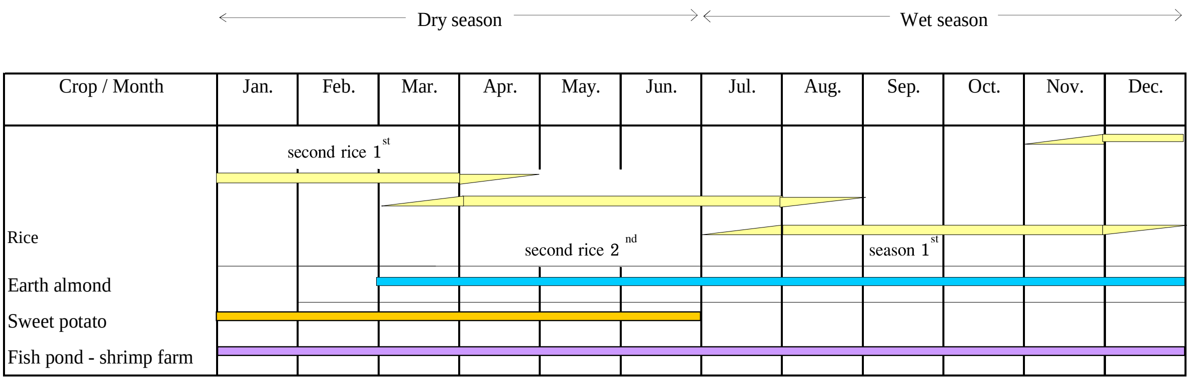



Figure 3.25 Crop calendars of PPP

### 3.3.2.2 Climatic station

There are nineteen and sixteen stations in the KPP and PPP, respectively as shown in Figure 3.26 and Figure 3.27. Rainfall, temperature and relative humidity are considered as the factors affecting the irrigation system. The average data of climatic conditions in KPP and PPP are shown in Table A-8 to A-13 respectively.

***Rainfall data***

Rainfall data was recorded monthly from 1993 to 2007. There were ten and twelve stations in the KPP and PPP respectively as shown in Figure 3.26 and Figure 3.27.

***Temperature data***

Temperature data was recorded monthly from 1993 to 2007. There were nine and four stations in the KPP and PPP respectively as shown in Figure 3.26 and Figure 3.27.

***Relative humidity data***

Relative humidity data was recorded monthly from 1993 to 2007. There were nine and four stations in the KPP and PPP respectively as shown in Figure 3.26 and Figure 3.27.

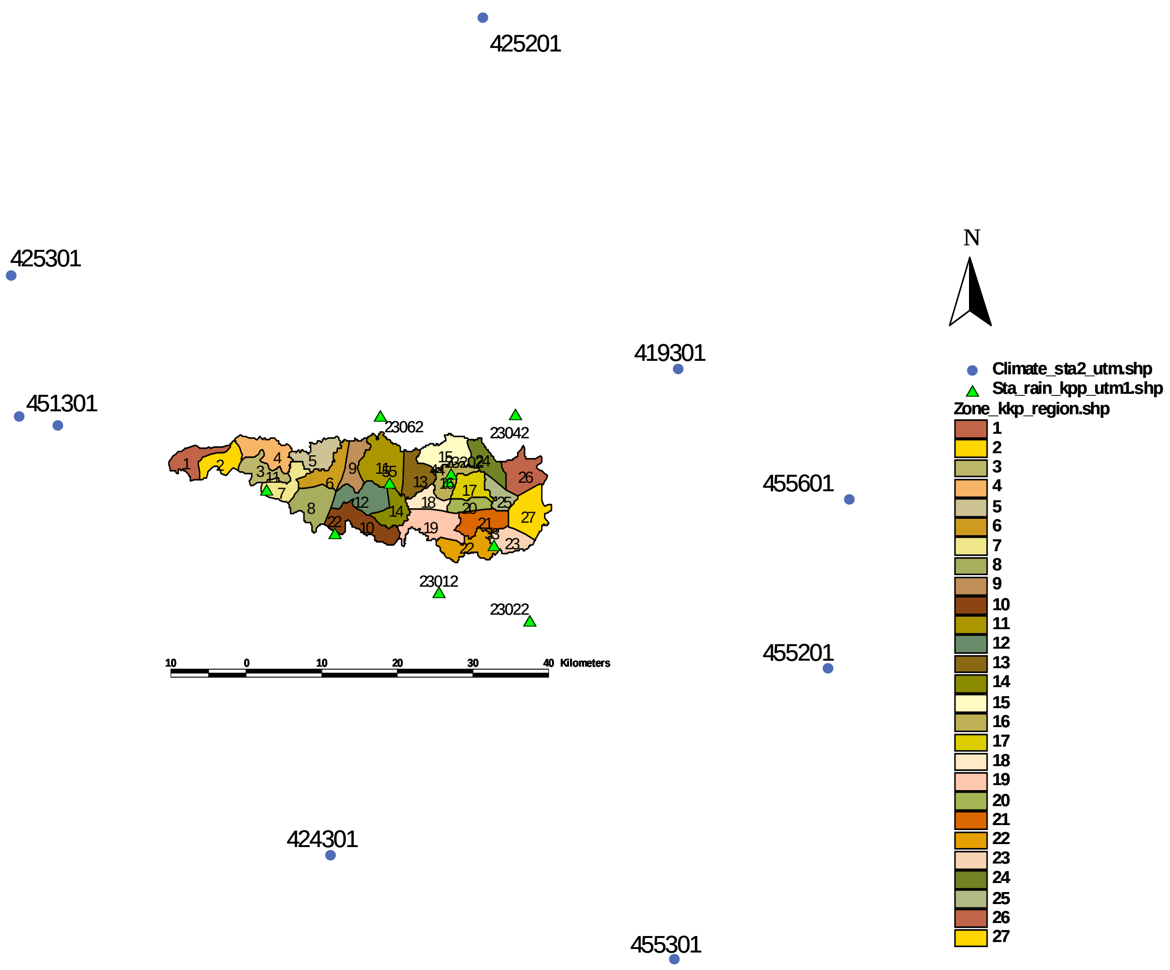



Figure 3.26 Climatic stations at KPP

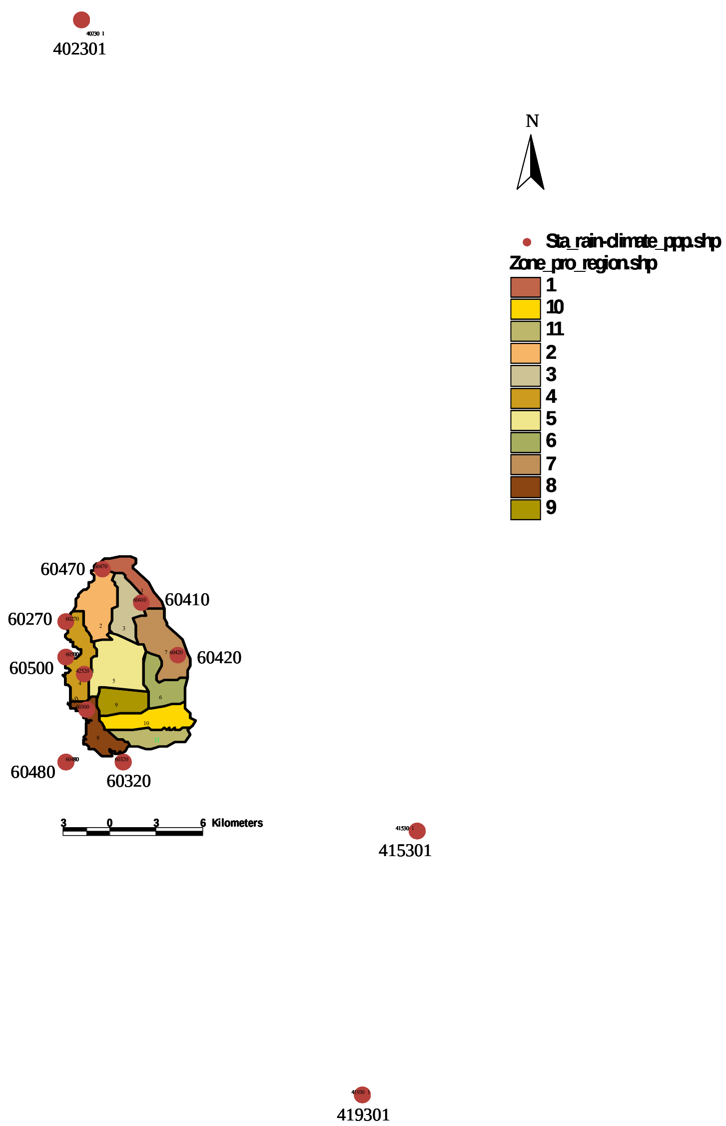



Figure 3.27 Climatic stations at PPP

### 3.3.2.3 Discharge

Discharge was used to compare delivered and planned flow. Flow data was collected from two projects. It was collected from 27 stations in KPP during the period of June 2006 to June 2007. In PPP, it was obtained from five stations during the period of June 2006 to April 2007.

### 3.3.2.4 Digital elevation models

Digital Elevation Model (DEM) data files are digital representations of cartographic information in a raster form. DEM consists of a sampled array of elevations for a number of ground positions at regularly spaced intervals. These digital cartographic/geographic data files are produced by the U.S. Geological Survey (USGS, 2005). DEM maps of KPP and PPP are shown in Figure 3.28 and Figure 3.29.

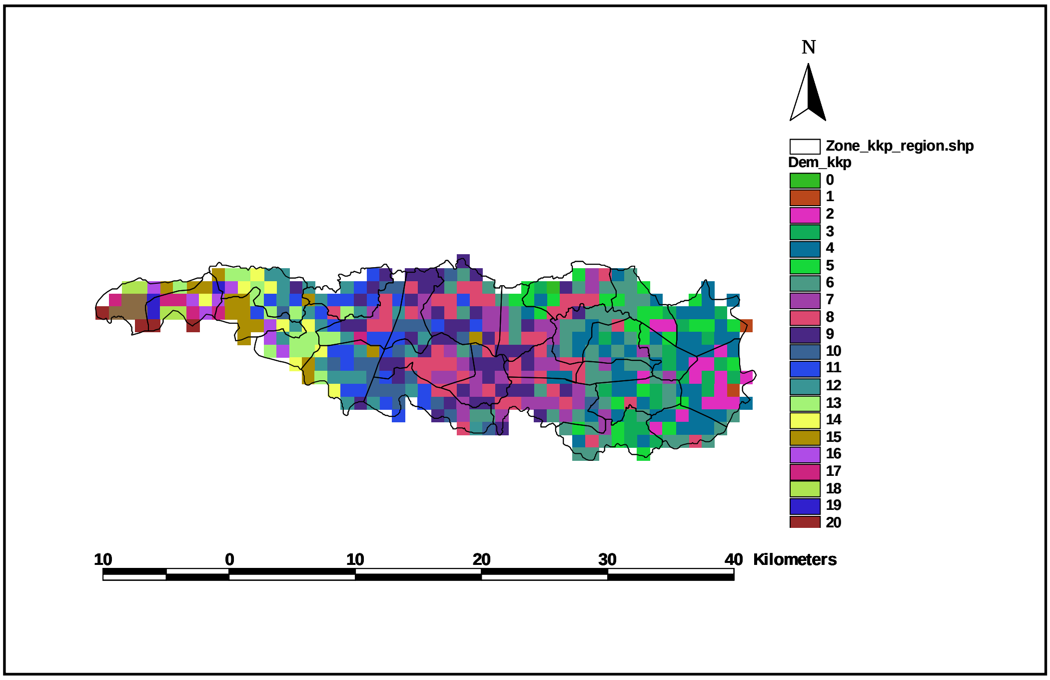



Figure 3.28 Digital elevation model at KPP

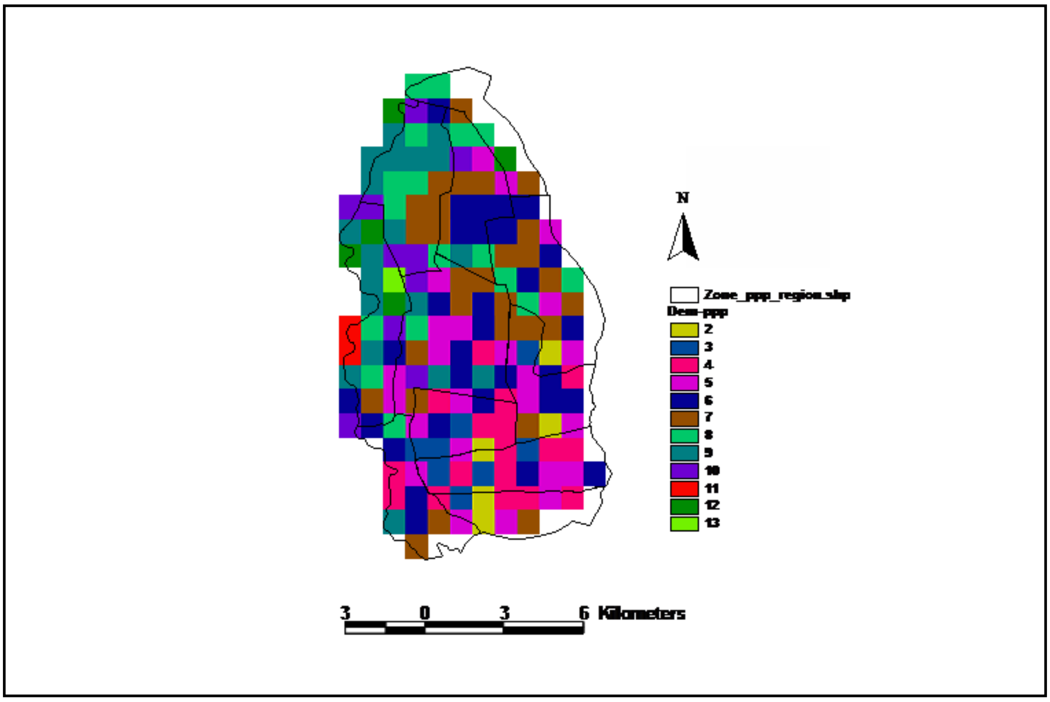



Figure 3.29 Digital elevation model at PPP

### 3.3.2.5 Drained water quality

Drained water quality parameters were collected at drainage canal every week in KPP. Drainage system of KPP separates from the irrigation system. Only irrigation canal 2L-5L, water was drained to drainage canal D-1L (Tharuae-Bangpra) at the tail end. If the parameter values of drained water are lower than the standard of water quality, the RID staff visits the site to find out the cause and solution. There are 24 stations in the KPP. The data of drained water quality are shown in Table A-14 and A-15. The locations of drained water sampling are shown in Figure 3.30. Dry season means 1 January to 30 June 2007and wet season means 1 July to 31 December 2007.

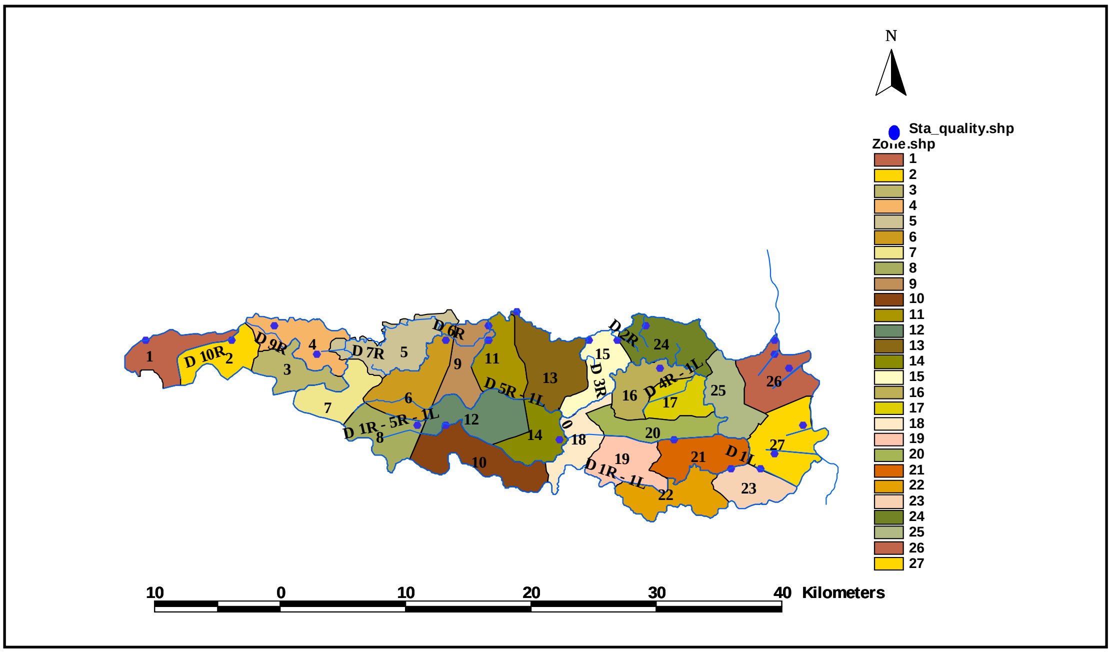



Figure 3.30 Drained water sampling points in KPP

Water quality parameters were collected along Tha Chin River every week in PPP as shown in Figure 3.31. There were four stations in PPP. Average parameter values were divided into wet and dry season using weekly data start from January to December 2007 as shown in Table A-16 and A-17.

To compare drained water quality using parameter of water quality standard for drained water as shown in Table A-18.

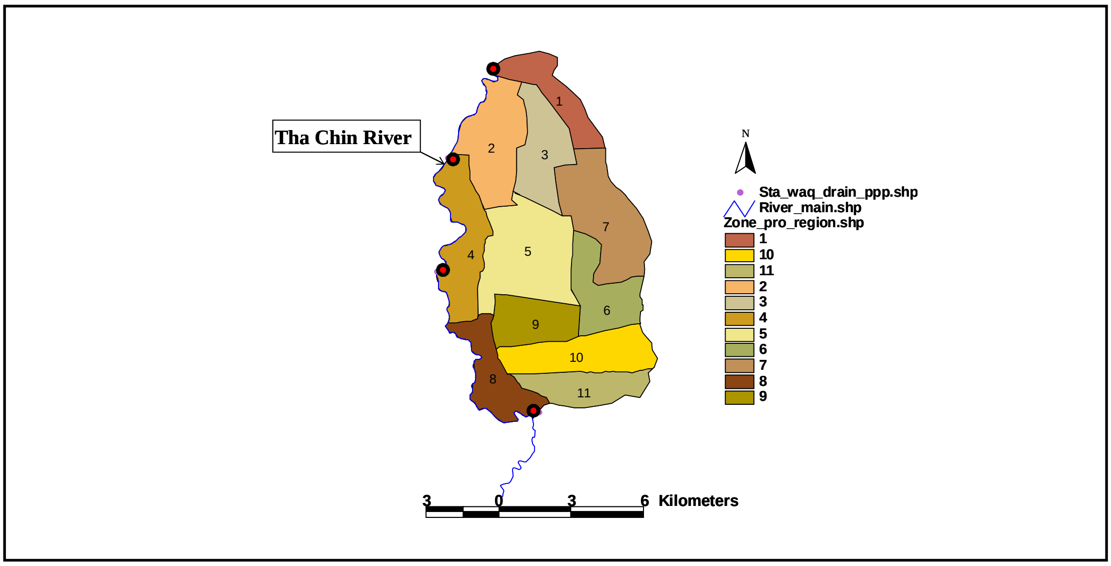



Figure 3.31 Drained water sampling points in PPP

## 3.4 Data Analysis and Classification

All data were converted into numeric values in their positive direction i.e. high scores indicated high optimism. According to IRRC (2009), the variables should be quantitative at the interval or ratio scale. Categorical data are not suitable for principal component analysis (PCA). Four categories of indicators were integrated using PCA. Their details are shown as follows.

### 3.4.1 Physical category

Physical factor is one of the main factors considered including climatic conditions (rainfall, temperature and relative humidity), soil property (soil fertility), irrigation water supply (flow ratio, field application ratio), topography (elevation) and relative location of irrigated area (location and relative elevation of water resource), ditch and drainage ditch condition and flooding frequency.

#### 3.4.1.1 Climatic conditions

In this study, climatic conditions such as rainfall, temperature and relative humidity were considered. These data have been displayed on the isohyets map of average monthly rainfall**,** average mean temperature and average relative humidity.

1) Rainfall

The average monthly rainfall for 15-year period (1993-2007) of KPP and PPP are shown in Table A-8, Figure B-1, Table A-11 and Figure B-4, respectively. These data have been displayed on isohyets map of average monthly rainfall in wet season (July to December) and dry season (January to June). Figure B-7 to B-8 and Figure B-13 to B-14 show isohyets map of average monthly rainfall of KPP and PPP in wet and dry season. The average rainfall data of each zone in KPP and PPP are shown in Table 3.9 and Table 3.10.

2) Temperature

The average mean temperature for 15-year period (1993-2007) of KPP and PPP are shown in Table A-9, Figure B-2, Table A-12 and Figure B-5, respectively. These data have been displayed on isohyets map of average mean temperature in wet season (July to December) and dry season (January to June). Figure B-9 to B-10 and Figure B-15 to B-16 show isohyets map of average mean temperature of KPP and PPP in wet and dry season. The average mean temperature data of each zone in KPP and PPP are shown in Table 3.9 and Table 3.10.

3) Relative humidity

The average relative humidity for 15-year period (1993-2007) of KPP and PPP are shown in Table A-10, Figure B-3, Table A-13 and Figure B-6, respectively. These data have been displayed on isohyets map of average relative humidity in wet season (July to December) and dry season (January to June). Figure B-11 to B-12 and Figure B-17 to B-18 show isohyets map of average relative humidity in wet and dry season, respectively. The average relative humidity of each zone in KPP and PPP are shown in Table 3.9 and Table 3.10.

Table 3.9 Climatic Data of KPP in Wet Season and Dry Season

| Zone | Climatic Data in Wet Season (1993-2007) | | | Climatic Data in Dry Season (1993-2007) | | |
|---|---|---|---|---|---|---|
| | Rainfall (mm.) | Temperature (°C) | Relative Humidity (%) | Rainfall (mm.) | Temperature (°C) | Relative Humidity (%) |
| 1 | 108±3 | 27.0±0.3 | 73.5±0.2 | 54±3 | 28.70±0.1 | 67.9±0.5 |
| 2 | 108±3 | 27.0±0.3 | 73.5±0.2 | 54±3 | 28.75±0.1 | 67.9±0.5 |
| 3 | 108±3 | 27.5±0.3 | 73.4±0.2 | 54±3 | 28.75±0.1 | 68.0±0.5 |
| 4 | 108±3 | 27.5±0.3 | 73.3±0.2 | 54±3 | 28.75±0.1 | 68.0±0.5 |
| 5 | 107±3 | 27.5±0.3 | 73.3±0.2 | 51±3 | 28.75±0.1 | 68.2±0.5 |
| 6 | 106±3 | 27.6±0.3 | 73.3±0.2 | 51±3 | 28.80±0.1 | 68.3±0.5 |
| 7 | 107±3 | 27.5±0.3 | 73.4±0.2 | 54±3 | 28.75±0.1 | 68.1±0.5 |
| 8 | 105±3 | 27.5±0.3 | 73.4±0.2 | 50±3 | 28.75±0.1 | 68.2±0.5 |
| 9 | 102±3 | 27.6±0.3 | 73.3±0.2 | 49±3 | 28.80±0.1 | 68.4±0.5 |
| 10 | 103±3 | 27.6±0.3 | 73.4±0.2 | 49±3 | 28.80±0.1 | 68.6±0.5 |
| 11 | 100±3 | 27.6±0.3 | 73.3±0.2 | 48±3 | 28.80±0.1 | 68.6±0.5 |
| 12 | 100±3 | 27.6±0.3 | 73.4±0.2 | 49±3 | 28.80±0.1 | 68.5±0.5 |
| 13 | 104±3 | 27.6±0.3 | 73.2±0.2 | 51±3 | 28.85±0.1 | 68.7±0.5 |
| 14 | 101±3 | 27.6±0.3 | 73.4±0.2 | 50±3 | 28.80±0.1 | 68.7±0.5 |
| 15 | 107±3 | 27.0±0.3 | 73.0±0.2 | 50±3 | 28.90±0.1 | 69.0±0.5 |
| 16 | 106±3 | 27.0±0.3 | 73.1±0.2 | 54±3 | 28.90±0.1 | 69.0±0.5 |
| 17 | 106±3 | 27.0±0.3 | 73.1±0.2 | 52±3 | 28.90±0.1 | 69.1±0.5 |
| 18 | 106±3 | 27.6±0.3 | 73.3±0.2 | 52±3 | 28.85±0.1 | 68.9±0.5 |
| 19 | 106±3 | 27.6±0.3 | 73.4±0.2 | 54±3 | 28.85±0.1 | 68.9±0.5 |
| 20 | 107±3 | 27.0±0.3 | 73.2±0.2 | 56±3 | 28.90±0.1 | 69.1±0.5 |
| 21 | 107±3 | 27.0±0.3 | 73.2±0.2 | 58±3 | 28.90±0.1 | 69.2±0.5 |
| 22 | 112±3 | 27.0±0.3 | 73.4±0.2 | 58±3 | 28.85±0.1 | 69.2±0.5 |
| 23 | 107±3 | 27.0±0.3 | 73.3±0.2 | 60±3 | 28.90±0.1 | 69.5±0.5 |
| 24 | 109±3 | 27.5±0.3 | 72.9±0.2 | 54±3 | 28.90±0.1 | 69.2±0.5 |
| 25 | 109±3 | 27.5±0.3 | 73.0±0.2 | 56±3 | 28.90±0.1 | 69.3±0.5 |
| 26 | 110±3 | 27.5±0.3 | 72.7±0.2 | 56±3 | 28.95±0.1 | 69.3±0.5 |
| 27 | 109±3 | 27.5±0.3 | 73.0±0.2 | 58±3 | 28.90±0.1 | 69.5±0.5 |

Table 3.10 Climatic Data of PPP in Wet Season and Dry Season

| Zone | Climatic Data in Wet Season (1993-2007) | | | Climatic Data in Dry Season (1993-2007) | | |
|---|---|---|---|---|---|---|
| | Rainfall (mm.) | Temperature (°C) | Relative Humidity (%) | Rainfall (mm.) | Temperature (°C) | Relative Humidity (%) |
| 1 | 83±15 | 27.4±0.04 | 75.5±0.3 | 40±9 | 28.5±0.1 | 70.1±0.3 |
| 2 | 135±15 | 27.3±0.04 | 75.9±0.3 | 70±9 | 28.5±0.1 | 71.2±0.3 |
| 3 | 105±15 | 27.4±0.04 | 75.6±0.3 | 50±9 | 28.5±0.1 | 71.0±0.3 |
| 4 | 110±15 | 27.3±0.04 | 76.0±0.3 | 55±9 | 28.5±0.1 | 71.3±0.3 |
| 5 | 108±15 | 27.4±0.04 | 75.7±0.3 | 53±9 | 28.5±0.1 | 71.0±0.3 |
| 6 | 90±15 | 27.4±0.04 | 75.2±0.3 | 43±9 | 28.6±0.1 | 70.6±0.3 |
| 7 | 80±15 | 27.4±0.04 | 75.3±0.3 | 37±9 | 28.6±0.1 | 70.7±0.3 |
| 8 | 107±15 | 27.4±0.04 | 75.7±0.3 | 50±9 | 28.5±0.1 | 71.2±0.3 |
| 9 | 105±15 | 27.4±0.04 | 75.6±0.3 | 50±9 | 28.5±0.1 | 71.0±0.3 |
| 10 | 103±15 | 27.4±0.04 | 75.3±0.3 | 48±9 | 28.6±0.1 | 70.8±0.3 |
| 11 | 103±15 | 27.4±0.04 | 75.1±0.3 | 48±9 | 28.6±0.1 | 70.7±0.3 |

#### 3.4.1.2 Soil property

Soil property was considered as important variable affecting the irrigation system and its sustainability. In this study, soil fertility was analyzed.

**1) Soil fertility**

Soil fertility is the characteristic of soil. It defines the ability of soil to support abundant nutrients as plant requires. It can be assessed from soil chemical properties i.e. organic matter (OM), cation exchange capacity (CEC), percent base saturation (% BS), available Phosphorus (P) and available Potassium (K). These properties can be attributed to soil fertility by total mark of each soil chemical property as shown in Table 3.11 to get the score and then compare the level of soil fertility. Based on the Land Development Department of Thailand (LDD, 2000) soil fertility was divided into three classes i.e. 1=low, 2=medium and 3=high. Table 3.11 shows level of soil fertility applied to three ranks namely low, medium and high.

Table 3.11 Level of Soil Fertility

| Level of Soil Fertility | OM (%) | BS (%) | CEC(cmol/kg) | P(mg/kg) | K(mg/kg) |
|---|---|---|---|---|---|
| Low | <1.5 | <35 | <10 | <10 | <60 |
| (Mark*) | (1) | (1) | (1) | (1) | (1) |
| Medium | 1.5-3.5 | 35-75 | 10-20 | 10-25 | 60-90 |
| (Mark*) | (2) | (2) | (2) | (2) | (2) |
| High | >3.5 | >75 | >20 | >25 | >90 |
| (Mark*) | (3) | (3) | (3) | (3) | (3) |

(LDD, 2000)

Note: Mark* (5-7) = Soil fertility is low (Score =1)
Mark* (8-12) = Soil fertility is medium (Score =2)
Mark* (13-15) = Soil fertility is high (Score =3)

The result of soil fertility in KPP is shown in Table 3.12. It was found that among 27 zones of KPP, 21 zones had high fertility level and 6 zones had a medium fertility level. It indicated that soil fertility in two projects was good.

Table 3.12 Soil Fertility in KPP

| Zone | OM(%) | | BS (%) | | CEC (cmol/kg) | | P (mg/kg) | | K (mg/kg) | | Total Mark | Soil Fertility |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.40 | 2 | 97.55 | 3 | 22.03 | 3 | 11.50 | 2 | 68.50 | 2 | 12 | 2 |
| 2 | 2.36 | 2 | 93.52 | 3 | 17.29 | 2 | 11.00 | 2 | 95.00 | 3 | 12 | 2 |
| 3 | 1.69 | 2 | 99.51 | 3 | 18.2 | 2 | 21.33 | 2 | 106.33 | 3 | 12 | 2 |
| 4 | 2.33 | 2 | 89.33 | 3 | 16.98 | 2 | 34.94 | 3 | 206.25 | 3 | 13 | 3 |
| 5 | 2.45 | 2 | 86.36 | 3 | 15.47 | 2 | 27.50 | 3 | 157.50 | 3 | 13 | 3 |
| 6 | 2.31 | 2 | 100 | 3 | 16.2 | 2 | 54.00 | 3 | 122.67 | 3 | 13 | 3 |
| 7 | 2.95 | 2 | 100 | 3 | 18.66 | 2 | 137.67 | 3 | 184.00 | 3 | 13 | 3 |
| 8 | 2.12 | 2 | 100 | 3 | 17.57 | 2 | 38.67 | 3 | 143.00 | 3 | 13 | 3 |
| 9 | 2.34 | 2 | 96.7 | 3 | 15.74 | 2 | 100.00 | 3 | 208.00 | 3 | 13 | 3 |
| 10 | 1.73 | 2 | 100 | 3 | 16.75 | 2 | 238.33 | 3 | 178.00 | 3 | 13 | 3 |
| 11 | 2.42 | 2 | 100 | 3 | 16.75 | 2 | 180.67 | 3 | 164.00 | 3 | 13 | 3 |
| 12 | 1.77 | 2 | 100 | 3 | 13.01 | 2 | 192.25 | 3 | 171.00 | 3 | 13 | 3 |
| 13 | 3.24 | 2 | 94.18 | 3 | 18.57 | 2 | 11.50 | 2 | 159.00 | 3 | 12 | 2 |
| 14 | 1.96 | 2 | 100 | 3 | 10.96 | 2 | 36.50 | 3 | 117.92 | 3 | 13 | 3 |
| 15 | 2.10 | 2 | 91.5 | 3 | 21.3 | 3 | 33.78 | 3 | 119.76 | 3 | 14 | 3 |
| 16 | 1.63 | 2 | 98.61 | 3 | 15.11 | 2 | 68.50 | 3 | 100.50 | 3 | 13 | 3 |
| 17 | 3.75 | 3 | 84.7 | 3 | 24.58 | 3 | 17.00 | 2 | 234.00 | 3 | 14 | 3 |
| 18 | 1.74 | 2 | 100 | 3 | 12.83 | 2 | 34.00 | 3 | 79.67 | 2 | 12 | 2 |
| 19 | 2.70 | 2 | 100 | 3 | 12.37 | 2 | 75.67 | 3 | 99.33 | 3 | 13 | 3 |
| 20 | 2.91 | 2 | 93.79 | 3 | 20.3 | 3 | 15.00 | 2 | 180.00 | 3 | 13 | 3 |
| 21 | 3.09 | 2 | 100 | 3 | 21.76 | 3 | 8.50 | 1 | 180.00 | 3 | 12 | 2 |
| 22 | 3.53 | 3 | 100 | 3 | 22.12 | 3 | 22.50 | 2 | 91.00 | 3 | 14 | 3 |
| 23 | 2.81 | 2 | 85.52 | 3 | 24.58 | 3 | 11.00 | 2 | 162.00 | 3 | 13 | 3 |
| 24 | 1.92 | 2 | 100 | 3 | 20.97 | 3 | 28.50 | 3 | 147.00 | 3 | 14 | 3 |
| 25 | 2.80 | 2 | 91.36 | 3 | 29.86 | 3 | 20.50 | 2 | 285.00 | 3 | 13 | 3 |
| 26 | 2.52 | 2 | 92.44 | 3 | 31.23 | 3 | 27.00 | 3 | 282.00 | 3 | 14 | 3 |
| 27 | 2.55 | 2 | 99.88 | 3 | 25.95 | 3 | 23.33 | 2 | 174.00 | 3 | 13 | 3 |

Table 3.13 shows soil fertility in PPP. It found that among 11 zones had high fertility level. There had no problems on the soil characteristic because all parameters were considered good.

Table 3.13 Soil Fertility in PPP

| Zone | OM(%) | | BS (%) | | CEC (cmol/kg) | | P (mg/kg) | | K (mg/kg) | | Total Mark | Soil Fertility |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.13 | 2 | 84.94 | 3 | 25.76 | 3 | 46.25 | 3 | 138.50 | 3 | 14 | 3 |
| 2 | 3.94 | 3 | 91.60 | 3 | 21.66 | 3 | 80.33 | 3 | 122.67 | 3 | 15 | 3 |
| 3 | 3.33 | 2 | 88.51 | 3 | 29.77 | 3 | 25.25 | 3 | 66.75 | 2 | 13 | 3 |
| 4 | 3.55 | 3 | 86.88 | 3 | 20.12 | 3 | 44.00 | 3 | 144.67 | 3 | 15 | 3 |
| 5 | 3.98 | 3 | 93.84 | 3 | 25.80 | 3 | 55.75 | 3 | 153.00 | 3 | 15 | 3 |
| 6 | 3.93 | 3 | 84.79 | 3 | 28.41 | 3 | 16.67 | 2 | 219.00 | 3 | 14 | 3 |
| 7 | 5.14 | 3 | 85.41 | 3 | 34.33 | 3 | 100.75 | 3 | 180.75 | 3 | 15 | 3 |
| 8 | 5.18 | 3 | 78.29 | 3 | 22.48 | 3 | 33.75 | 3 | 126.25 | 3 | 15 | 3 |
| 9 | 4.04 | 3 | 92.45 | 3 | 31.14 | 3 | 23.67 | 2 | 119.33 | 3 | 14 | 3 |
| 10 | 4.78 | 3 | 83.91 | 3 | 31.14 | 3 | 32.75 | 3 | 211.50 | 3 | 15 | 3 |
| 11 | 4.01 | 3 | 124.03 | 3 | 25.76 | 3 | 16.33 | 2 | 164.00 | 3 | 14 | 3 |

Table 3.14 presents chemical properties of soil standard namely; OM (%), N (%), P, K, Ca, and Mg. Based on the Land Development Department of Thailand (LDD, 2000) chemical properties of soil can be classified into five levels such as very low, low, medium, high and very high.

Table 3.14 Chemical Properties of Soil

| Level of Soil Property | OM (%) | N (%) | P (mg/kg) | K (mg/kg) | Ca (mg/kg) | Mg (mg/kg) | Score |
|---|---|---|---|---|---|---|---|
| Very low | <1.0 | <0.025 | <3 | <30 | <400 | <36 | 1 |
| Low | 1.0-1.5 | 0.025-0.075 | 3-10 | 30-60 | 400-1000 | 36-120 | 2 |
| Medium | 1.6-2.5 | 0.076-0.125 | 11-15 | 61-90 | 1001-2000 | 121-365 | 3 |
| High | 2.6-3.5 | 0.126-0.175 | 16-45 | 91-120 | 2001-4000 | 366-975 | 4 |
| Very high | >3.5 | >0.175 | >45 | >120 | >4000 | >975 | 5 |

(LDD, 2000)

Table 3.15 presents chemical properties of soil and ranked score in KPP. When compared with chemical property standard (see Table 3.14), it was found that all of these properties got the level of soil property from medium to high level.

Table 3.15 Score of Chemical Properties of Soil in KPP

| Zone | Score of Chemical Properties of Soil | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OM (%) | Score | N (%) | Score | P (mg/kg) | Score | K (mg/kg) | Score | Ca (mg/kg) | Score | Mg (mg/kg) | Score |
| 1 | 2.40 | 3 | 0.12 | 3 | 11.50 | 3 | 68.50 | 3 | 3318.00 | 4 | 299.50 | 3 |
| 2 | 2.36 | 3 | 0.12 | 3 | 11.00 | 3 | 95.00 | 4 | 2863.67 | 4 | 235.33 | 3 |
| 3 | 1.69 | 3 | 0.09 | 3 | 21.33 | 4 | 106.33 | 4 | 3516.67 | 4 | 308.67 | 3 |
| 4 | 2.33 | 3 | 0.12 | 3 | 34.94 | 4 | 206.25 | 5 | 2439.06 | 4 | 249.81 | 3 |
| 5 | 2.45 | 3 | 0.13 | 4 | 27.50 | 4 | 157.50 | 5 | 2052.25 | 4 | 238.00 | 3 |
| 6 | 2.31 | 3 | 0.12 | 3 | 54.00 | 5 | 122.67 | 5 | 3163.33 | 4 | 252.67 | 3 |
| 7 | 2.95 | 4 | 0.12 | 3 | 137.67 | 5 | 184.00 | 5 | 3095.33 | 4 | 251.33 | 3 |
| 8 | 2.12 | 3 | 0.10 | 3 | 38.67 | 4 | 143.00 | 5 | 2893.00 | 4 | 318.67 | 3 |
| 9 | 2.34 | 3 | 0.12 | 3 | 100.00 | 5 | 208.00 | 5 | 2238.00 | 4 | 246.33 | 3 |
| 10 | 1.73 | 3 | 0.09 | 3 | 238.33 | 5 | 178.00 | 5 | 2453.00 | 4 | 448.67 | 4 |
| 11 | 2.42 | 3 | 0.12 | 3 | 180.67 | 5 | 164.00 | 5 | 4236.33 | 5 | 696.33 | 4 |
| 12 | 1.77 | 3 | 0.09 | 3 | 192.25 | 5 | 171.00 | 5 | 4576.50 | 5 | 427.25 | 4 |
| 13 | 3.24 | 4 | 0.17 | 4 | 11.50 | 3 | 159.00 | 5 | 3482.50 | 4 | 668.00 | 4 |
| 14 | 1.96 | 3 | 0.10 | 3 | 36.50 | 4 | 117.92 | 4 | 4429.42 | 5 | 602.33 | 4 |
| 15 | 2.10 | 3 | 0.10 | 3 | 33.78 | 4 | 119.76 | 4 | 4389.54 | 5 | 568.63 | 4 |
| 16 | 1.63 | 3 | 0.08 | 3 | 68.50 | 5 | 100.50 | 4 | 2159.50 | 4 | 392.00 | 4 |
| 17 | 3.75 | 5 | 0.19 | 4 | 17.00 | 4 | 234.00 | 5 | 2592.00 | 4 | 879.50 | 4 |
| 18 | 1.74 | 3 | 0.09 | 3 | 34.00 | 4 | 79.67 | 3 | 1665.33 | 3 | 266.33 | 3 |
| 19 | 2.70 | 4 | 0.14 | 4 | 75.67 | 5 | 99.33 | 4 | 1992.00 | 3 | 406.00 | 4 |
| 20 | 2.91 | 4 | 0.15 | 4 | 15.00 | 3 | 180.00 | 5 | 2254.00 | 4 | 738.50 | 4 |
| 21 | 3.09 | 4 | 0.16 | 4 | 8.50 | 2 | 180.00 | 5 | 3121.50 | 4 | 854.00 | 4 |
| 22 | 3.53 | 5 | 0.18 | 4 | 22.50 | 4 | 91.00 | 4 | 2349.00 | 4 | 720.00 | 4 |
| 23 | 2.81 | 4 | 0.14 | 4 | 11.00 | 3 | 162.00 | 5 | 1964.00 | 3 | 670.50 | 4 |
| 24 | 1.92 | 3 | 0.10 | 3 | 28.50 | 4 | 147.00 | 5 | 4981.50 | 5 | 841.50 | 4 |
| 25 | 2.80 | 4 | 0.14 | 4 | 20.50 | 4 | 285.00 | 5 | 4500.00 | 5 | 1237.50 | 5 |
| 26 | 2.52 | 3 | 0.13 | 4 | 27.00 | 4 | 282.00 | 5 | 6175.50 | 5 | 1266.50 | 5 |
| 27 | 2.55 | 3 | 0.13 | 4 | 23.33 | 4 | 174.00 | 5 | 3339.67 | 4 | 1059.33 | 5 |

Table 3.16 presents chemical properties of soil and ranked score in PPP. The results showed that all of these properties got the level of soil property from high to very high level.

Table 3.16 Score of Chemical Properties of Soil in PPP

| Zone | Score of Chemical Properties of Soil | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OM (%) | Score | N (%) | Score | P (mg/kg) | Score | K (mg/kg) | Score | Ca (mg/kg) | Score | Mg (mg/kg) | Score |
| 1 | 3.13 | 4 | 0.16 | 4 | 46.25 | 5 | 138.50 | 5 | 4884.00 | 5 | 534.00 | 4 |
| 2 | 3.94 | 5 | 0.20 | 4 | 80.33 | 5 | 122.67 | 5 | 3876.00 | 4 | 468.67 | 4 |
| 3 | 3.33 | 4 | 0.17 | 4 | 25.25 | 4 | 66.75 | 3 | 3733.50 | 4 | 465.25 | 4 |
| 4 | 3.55 | 5 | 0.18 | 4 | 44.00 | 4 | 144.67 | 5 | 3804.33 | 4 | 490.67 | 4 |
| 5 | 3.98 | 5 | 0.20 | 4 | 55.75 | 5 | 153.00 | 5 | 5136.00 | 5 | 746.25 | 4 |
| 6 | 3.93 | 5 | 0.20 | 4 | 16.67 | 4 | 219.00 | 5 | 5734.33 | 5 | 809.00 | 4 |
| 7 | 5.14 | 5 | 0.26 | 5 | 100.75 | 5 | 180.75 | 5 | 6214.50 | 5 | 572.25 | 4 |
| 8 | 5.18 | 5 | 0.26 | 5 | 33.75 | 4 | 126.25 | 5 | 4366.25 | 5 | 612.75 | 4 |
| 9 | 4.04 | 5 | 0.20 | 4 | 23.67 | 4 | 119.33 | 4 | 5994.67 | 5 | 680.33 | 4 |
| 10 | 4.78 | 5 | 0.24 | 5 | 32.75 | 4 | 211.50 | 5 | 5781.00 | 5 | 689.50 | 4 |
| 11 | 4.01 | 5 | 0.20 | 4 | 16.33 | 4 | 164.00 | 5 | 5970.00 | 5 | 576.33 | 4 |

### 3.4.1.3 Irrigation water supply

The quantity of irrigation water supply was observed during the study period, the ratio of delivered to planned flow matched. Field application ratio (volume of water supplied and volume of water demand) indicated how volume of water supply and volume of water demand matched where a value higher than 1 means too much water is being supplied. On the other hand, value lower than 1 indicated that crops were not getting enough water.

**1) Flow ratio**

Flow ratio (delivered flow /planned flow) can be used to quantify the planning process and water distribution at the canal regulator structure or check structure. The schematic diagrams of canal system in KPP and PPP are shown in Figure 3.14 and Figure 3.23 respectively.

In KPP, planning process was done weekly. Zoneman surveyed the cultivated area and calculated the required flow every week on Tuesday to summarize the plan flow and then proposed to chief of water allocation division. Then they distributed water to the control structure in the canal system. On the other hand, PPP has no weekly planning process. Instead, there was a pre-season plan in both seasons to allocate a quantity of water for the whole season in the project. The seasonal plan is based on official assumptions considering the cropping calendar. The gate operating rules in this project were vague. RID staffs did not follow the rules and they operated based on their experiences. However, there was no problem on distribution of water, though it did not produce equal distribution of water.

KPP starts gate operation in dry season during February to June and wet season during mid of July to first December. PPP starts gate operation in dry season during November to April and wet season during June to October. The planned and delivered flow in wet and dry season for KPP and PPP are illustrated in Table A-19 to A-20 and Table A-21 to A-22 respectively.

Flow ratio is defined as (delivered flow/planned flow) which has reference to level of allocation. The flow ratio is divided into 5 scales (1=very low ratio, 2=low ratio, 3=medium, 4= high ratio and 5=very high ratio) according to level of allocation water such as allocate water ratio less than 0.6 indicate very low ratio, low ratio for 0.6-0.69, medium for 0.70-0.79, high ratio for 0.80-0.89 and very high ratio for 0.9. Table 3.17 shows the score of flow ratio in KPP and PPP. Relationship of canals and zone boundaries in KPP and PPP are shown in Table A-23 and A-24.

Table 3.17 Score of Flow Ratio in KPP and PPP

| Zone | Kamphaengsaen (KPP) | | Phophraya(PPP) | |
|---|---|---|---|---|
| | Wet Season (Score) | Dry Season (Score) | Wet Season (Score) | Dry Season (Score) |
| 1 | 1 | 1 | 3 | 2 |
| 2 | 3 | 4 | 5 | 5 |
| 3 | 2 | 3 | 3 | 2 |
| 4 | 5 | 5 | 5 | 4 |
| 5 | 5 | 5 | 4 | 3 |
| 6 | 5 | 5 | 3 | 2 |
| 7 | 5 | 5 | 3 | 2 |
| 8 | 5 | 5 | 4 | 3 |
| 9 | 5 | 3 | 4 | 3 |
| 10 | 3 | 4 | 4 | 3 |
| 11 | 4 | 3 | 3 | 3 |
| 12 | 3 | 4 | | |
| 13 | 4 | 3 | | |
| 14 | 2 | 4 | | |
| 15 | 4 | 4 | | |
| 16 | 2 | 4 | | |
| 17 | 2 | 4 | | |
| 18 | 4 | 4 | | |
| 19 | 5 | 5 | | |
| 20 | 5 | 5 | | |
| 21 | 2 | 5 | | |
| 22 | 5 | 5 | | |
| 23 | 2 | 2 | | |
| 24 | 5 | 3 | | |
| 25 | 5 | 5 | | |
| 26 | 3 | 1 | | |
| 27 | 5 | 5 | | |

**2) Field application ratio**

Field application ratio (volume of water supplied / volume of water demand) indicates that how volume of water supply and volume of water demand are match, a value higher than 1 means too much water is being supply. On the other hand, value lower than 1 indicates that crops are not getting enough water. In this study the volume of water supplied was considered as amount of irrigation water delivered to the field and volume of water demand is considered as crop water requirement minus the effective rainfall. According to

Smith (1992) and Allen et al. (1998) cited in Phengphaengsy and Okudaira (2008), the water requirement for each practice is defined as follows:

Water demand (Irrigation water demand)

$$WD = (Etc-Pe) \tag{3.1}$$

Water requirement for non-paddy crops

$$ETc = ETo \times Kc \tag{3.2}$$

Water Requirement for Paddy Crops

$$ETc = ETo \times Kc + P + LP \tag{3.3}$$

Water Requirement for Fish Ponds and Shrimp Farms

$$ETc = ETo \times Kc + P \tag{3.4}$$

Where;

WD = Water demand (Irrigation water demand) (mm/day)
Pe = Effective rainfall (mm/day)
Etc = Crop water consumption (mm/day)
ETo = Reference evapotranspiration (mm/day)
Kc = Crop coefficient
LP = Land preparation (mm/day)
P = Percolation (mm/day)

In KPP, there is diversity of crops such as rice, sugarcane, farm crop, shrimp farm and fish pond. Table A-25 and Table A-26 show the type of crops and cultivated area. This is used to determine water requirement in wet and dry season for KPP during 7 August to 26 November 2006 (week 7-22) and during 12 February to 3 June 2007 (week 7-22), respectively.

Table A-27 and Table A-28 show the type of crops and cultivated area. This is used to determine water requirement in wet season for PPP during 3 August to 31 October 2006 (week 10-22) and dry season during 30 December 2006 to 30 April 2007(week 10-22).

The average monthly data such as temperature, relative humidity and wind were used to determine the reference evapotranspiration (ETo) of KPP and PPP as shown in Table A-29 and A-30. Table A-31 and A-32 show crop coefficient (Kc) data for different crops on week and month. Rice crop, in this study used plus 1.5 mm/day for seepage losses.

The quantity of the source of water can have a significant impact on the irrigation practices. The ratio of volume supply and volume demand can be divided into five scales (1=very low ratio, 2=low ratio, 3=medium, 4= high ratio and 5=very high ratio). This ratio was determined by comparing the ratio of volume water supply and water demand. Based on Bos et al. (2005) maximum attainable values of the field application ratio for irrigation water application method (sprinkler) is 0.9. If the ratio less than 0.6, it is labeled very low ratio, low ratio for 0.6-0.69, medium for 0.70-0.79, high ratio for 0.80-0.89 and very high ratio for 0.9.

Field application ratio of KPP is calculated in wet and dry season during 7 August to 26 November 2006 (week 7-22) and 12 February to 3 June 2007(week 7-22). On the other hand, PPP was calculated in wet and dry season during 3 August to 31 October 2006 (week 10-22) and 30 December 2006 to 30 April 2007(week 10-22). The weekly volume of water which enters the main intake was considered as the volume supply. The crop water requirement was calculated as the volume of water demand. The Penman–Monteint method was used to calculate the crop water requirement. In this study, field application ratio was calculated on main and secondary canals and then average score of field application ratio into each zone. Scores of field application ratio of KPP and PPP in wet season and dry season are shown in Table 3.18.

Table A-33 to A-34 and Table A-35 to A-36 present field application ratio on week of KPP and PPP in wet and dry season, respectively.

Table 3.18 Score of Field Application Ratio for KPP and PPP

| Zone | Kamphaengsaen (KPP) | | Phophraya(PPP) | |
|---|---|---|---|---|
| | Wet Season (Score) | Dry Season (Score) | Wet Season (Score) | Dry Season (Score) |
| 1 | 1 | 1 | 3 | 2 |
| 2 | 3 | 4 | 5 | 5 |
| 3 | 2 | 3 | 3 | 2 |
| 4 | 5 | 5 | 5 | 4 |
| 5 | 5 | 5 | 4 | 3 |
| 6 | 5 | 5 | 3 | 2 |
| 7 | 5 | 5 | 3 | 2 |
| 8 | 5 | 5 | 4 | 3 |
| 9 | 5 | 3 | 4 | 3 |
| 10 | 3 | 4 | 4 | 3 |
| 11 | 4 | 3 | 3* | 3* |
| 12 | 3 | 4 | | |
| 13 | 4 | 3 | | |
| 14 | 2 | 4 | | |
| 15 | 4 | 4 | | |
| 16 | 2 | 4 | | |
| 17 | 2 | 4 | | |
| 18 | 4 | 4 | | |
| 19 | 5 | 5 | | |
| 20 | 5 | 5 | | |
| 21 | 2 | 5 | | |
| 22 | 5 | 5 | | |
| 23 | 2 | 2 | | |
| 24 | 5 | 3 | | |
| 25 | 5 | 5 | | |
| 26 | 3 | 1 | | |
| 27 | 5 | 5 | | |

Remark: 3* means a score of 3 was given to zone 11 because this zone has no irrigation system

### 3.4.1.4 Topography

Topography is a major factor affecting irrigation system to concern. Upper part on the west of the KPP near Mae Klong River such as zone 1, zone 2, zone 3, and zone 4 is the plain area and has quite an extensive slope towards the end of east near Nakhon Chaisi River such as zone 26 and zone 27. On the other hand, PPP is a plain area. There is quite an extensive slope from North (zone 1, 2 and 3) to South (zone 9, 10, 11). The elevations of zone areas at KPP and PPP are shown in Table 3.19.

Table 3.19 Elevation of Zone Areas for KPP and PPP

| KPP | | PPP | |
|---|---|---|---|
| Zone | Elevation (m.) | Zone | Elevation (m.) |
| 1 | 18.6 | 1 | 8.32 |
| 2 | 17.1 | 2 | 8.53 |
| 3 | 14.7 | 3 | 7.00 |
| 4 | 13.3 | 4 | 9.77 |
| 5 | 10.8 | 5 | 6.73 |
| 6 | 10.4 | 6 | 5.17 |
| 7 | 13.2 | 7 | 6.31 |
| 8 | 12.0 | 8 | 5.38 |
| 9 | 9.4 | 9 | 4.25 |
| 10 | 9.5 | 10 | 4.21 |
| 11 | 8.4 | 11 | 4.12 |
| 12 | 8.5 | | |
| 13 | 6.8 | | |
| 14 | 8.4 | | |
| 15 | 6.2 | | |
| 16 | 6.1 | | |
| 17 | 5.0 | | |
| 18 | 7.3 | | |
| 19 | 7.2 | | |
| 20 | 5.4 | | |
| 21 | 4.7 | | |
| 22 | 4.8 | | |
| 23 | 4.4 | | |
| 24 | 4.8 | | |
| 25 | 4.6 | | |
| 26 | 4.0 | | |
| 27 | 2.8 | | |

### 3.4.1.5 Relative location of irrigated area

This factor considered a location of sub-main canal in the field and relative position of irrigated area to water resource. The location of sub-main canal in the field can be classified into 3 groups i.e. 1=upstream, 2=middle and 3=downstream. The relative position of irrigated area to water resource can be classified into 3 groups i.e. 1=higher slope, 2=average the same level and 3=lower slope. The results of location of sub-main canal in the field and relative position of irrigated area to water resource for KPP and PPP are presented in Table D-1 and Table D-5 respectively.

#### 3.4.1.6 Ditch and drainage ditch condition

These factors address the degree of satisfaction of farmers on the condition of ditch (canal) and drainage ditch system in terms of cleanliness and smoothness. It is classified into five levels, i.e. 1=strongly dissatisfied, 2=dissatisfied, 3=neutral, 4=satisfied, 5=strongly satisfied. The results of farmer's satisfaction of canal and drainage condition as shown in Table D-1 and Table D-5 respectively.

#### 3.4.1.7 Flooding frequency

Flooding frequency means how often farmers have ever experienced flood in their fields. To get information on it, this study used questionnaire interview to ask farmers about their experiences of flooding in their fields. It is divided into five groups (i.e. 1=no flood within 2-3 recent years, 2=every year, 3=twice a year, 4=depend on depression and 5= occasion). The results of flooding frequency in KPP and PPP are presented in Table D-1 and D-5 respectively.

### 3.4.2 Socio-economic category

Socio-economic factor involved many parameters such as household size, age structure, education of farmers, experience of farmers, land tenure, crop yield, production cost, farm income and net farm income. Data analysis was conducted in order to get information on the socio-economic conditions of the project. These data were integrated with physical, institutional and environment data in the principal component analysis.

#### 3.4.2.1 Socio economic condition

1) House hold size

The number of respondents were 1,391 and 462 in KPP and PPP. Household survey was conducted in 27 and 11 zones of KPP and PPP respectively. Table 3.20 and 3.21 present the household classification of each zone in KPP and PPP. The size group can be classified into five groups such as less than 2 persons, 3-4 persons, 5-6 persons, 7-8 persons, and more than 9 persons. Household size only counted the person(s) who stay and work with the farmer. The household size group of the KPP is slightly from small size (41.77%) to medium size (40.81%). The household size group of the PPP is slightly from small size (42.64%) to medium size (44.52%) as shown in Table 3.21.

Table 3.20 Household Size by Zones for KPP

| Zone | Household Size Group (%) | | | | |
|---|---|---|---|---|---|
| | ≤2 (persons/ household) | 3-4 (persons/ household) | 5-6 (persons/ household) | 7-8 (persons/ household) | ≥9 (persons/ household) |
| 1 | 16.1 | 45.2 | 29 | 9.7 | - |
| 2 | 7.7 | 38.5 | 48.6 | 2.6 | 2.6 |
| 3 | 4.4 | 60 | 31.2 | 4.4 | - |
| 4 | 10 | 47.5 | 32.5 | 5 | 5 |
| 5 | 7.8 | 55.3 | 31.6 | 5.3 | - |
| 6 | 7.8 | 42.3 | 42.3 | 3.8 | 3.8 |
| 7 | 2.4 | 56.1 | 36.6 | 4.9 | - |
| 8 | 11.2 | 33.3 | 47.2 | 8.3 | - |
| 9 | 5.1 | 53.8 | 30.8 | 7.7 | 2.6 |
| 10 | - | 47.5 | 32.5 | 17.5 | 2.5 |
| 11 | 5.1 | 32.2 | 49.2 | 10.2 | 3.3 |
| 12 | 1.6 | 54.6 | 39.1 | 1.6 | 3.1 |
| 13 | 2.1 | 66.6 | 31.3 | - | - |
| 14 | 15 | 40 | 30 | 15 | - |
| 15 | - | 24.1 | 44.9 | 24.1 | 6.9 |
| 16 | 7.7 | 41.5 | 38.5 | 10.8 | 1.5 |
| 17 | 8.6 | 37.9 | 43.2 | 10.3 | - |
| 18 | 6 | 28 | 60 | 6 | - |
| 19 | - | 33.3 | 42.9 | 19 | 4.8 |
| 20 | 5.9 | 22.1 | 42.6 | 23.5 | 5.9 |
| 21 | 8.9 | 51.1 | 22.2 | 15.6 | 2.2 |
| 22 | 2 | 34.7 | 49 | 10.2 | 4.1 |
| 23 | 15 | 30 | 32.5 | 17.5 | 5 |
| 24 | - | 72.1 | 25.6 | 2.3 | - |
| 25 | - | 8.6 | 69 | 19 | 3.4 |
| 26 | 5.3 | 35.1 | 47.3 | 12.3 | - |
| 27 | 2.9 | 50 | 44.2 | 2.9 | - |
| Average | 7.21 | 42.27 | 39.77 | 10.37 | 3.78 |

Source : Field Survey, 2007

Table 3.21 Household Size by Zones for PPP

| Zone | Household Size Group (%) | | | | |
|---|---|---|---|---|---|
| | ≤2 (persons/ household) | 3-4 (persons/ household) | 5-6 (persons/ household) | 7-8 (persons/ household) | ≥9 (persons/ household) |
| 1 | 11.76 | 64.71 | 20.59 | 2.94 | - |
| 2 | 10.71 | 60.71 | 25 | 1.79 | 1.79 |
| 3 | 2.86 | 48.56 | 42.86 | 2.86 | 2.86 |
| 4 | 2.56 | 12.82 | 82.06 | 2.56 | - |
| 5 | 6 | 36 | 52 | 4 | 2 |
| 6 | 12.82 | 43.59 | 33.33 | 10.26 | - |
| 7 | - | 52.5 | 45 | 2.5 | - |
| 8 | - | 31.04 | 58.62 | 10.34 | - |
| 9 | 3.58 | 50 | 25 | 10.71 | 10.71 |
| 10 | 7.81 | 34.38 | 53.13 | 4.68 | - |
| 11 | - | 34.78 | 52.17 | 13.05 | - |
| Average | 7.26 | 42.64 | 44.52 | 5.97 | 4.34 |

Source : Field Survey, 2007

2) Age Structure

The age group can be divided into five ranges (less than 35 years, 35-45 years, 46-55 years, 56-65 years and more than 65 years). Table 3.22 shows the age structure of each zone in KPP. The average age of respondents in KPP is between 46-55 years by 36.73%.

Table 3.22 Age Structure by Zones in KPP

| Zone | Age Structure (%) | | | | |
|---|---|---|---|---|---|
| | <35 years | 35-45 years | 46-55 years | 56-65 years | >65 years |
| 1 | 12.1 | 24.2 | 36.4 | 21.2 | 6.1 |
| 2 | 5.3 | 28.9 | 34.2 | 31.6 | - |
| 3 | 8.9 | 22.2 | 28.9 | 17.8 | 22.2 |
| 4 | 7.7 | 30.8 | 28.2 | 20.5 | 12.8 |
| 5 | 2.7 | 21.6 | 21.6 | 35.2 | 18.9 |
| 6 | 9.1 | 31.8 | 18.2 | 36.4 | 4.5 |
| 7 | 13.6 | 20.5 | 34.1 | 29.5 | 2.3 |
| 8 | 8.3 | 33.3 | 30.6 | 22.2 | 5.6 |
| 9 | 14 | 34.7 | 30.3 | 16.3 | 4.7 |
| 10 | - | 34.2 | 39 | 12.2 | 14.6 |
| 11 | 6.8 | 22 | 28.8 | 27.1 | 15.3 |
| 12 | 8.7 | 33.3 | 29 | 20.3 | 8.7 |
| 13 | - | 14.3 | 69.4 | 16.3 | - |
| 14 | - | 35 | 30 | 30 | 5 |
| 15 | 37.9 | 10.3 | 10.3 | 41.5 | - |
| 16 | 12.3 | 24.6 | 32.3 | 12.3 | 18.5 |
| 17 | 8.6 | 39.7 | 36.2 | 12.1 | 3.4 |
| 18 | 11.8 | 39 | 27.1 | 8.5 | 13.6 |
| 19 | 11.1 | 22.3 | 24.4 | 33.3 | 8.9 |
| 20 | 1.5 | 23.5 | 42.6 | 23.5 | 8.9 |
| 21 | 2.3 | 24.4 | 44.4 | 15.6 | 13.3 |
| 22 | 8.3 | 25 | 43.8 | 20.8 | 2.1 |
| 23 | 17.5 | 17.5 | 17.5 | 20 | 27.5 |
| 24 | 4.1 | 24.5 | 57.1 | 10.2 | 4.1 |
| 25 | 6.9 | 15.5 | 41.4 | 29.3 | 6.9 |
| 26 | 1.8 | 14 | 57.9 | 15.8 | 10.5 |
| 27 | - | 15.7 | 54.3 | 28.6 | 1.4 |
| Average | 9.62 | 25.29 | 35.11 | 22.52 | 9.99 |

Source: Field Survey, 2007

Table 3.23 shows the age structure of each zone in PPP. The average age of respondents in PPP is between 46-55 years by 34.47%.

Table 3.23 Age Structure by Zones in PPP

| Zone | Age Structure (%) | | | | |
|---|---|---|---|---|---|
| | <35 years | 35-45 years | 46-55 years | 56-65 years | >65 years |
| 1 | 2.94 | 23.53 | 38.24 | 20.58 | 14.71 |
| 2 | 5.36 | 35.71 | 33.93 | 21.43 | 3.57 |
| 3 | 2.94 | 20.59 | 29.42 | 35.29 | 11.76 |
| 4 | - | - | 17.5 | 80 | 2.5 |
| 5 | 6.12 | 20.41 | 44.9 | 24.49 | 4.08 |
| 6 | 10 | 40 | 30 | 12.5 | 7.5 |
| 7 | - | 40 | 30 | 30 | - |
| 8 | 3.45 | 8.62 | 41.38 | 46.55 | - |
| 9 | 10.71 | 35.71 | 32.14 | 14.3 | 7.14 |
| 10 | 6.24 | 23.44 | 46.88 | 23.44 | - |
| 11 | 8.7 | 17.39 | 34.78 | 39.13 | - |
| Average | 6.27 | 26.54 | 34.47 | 31.61 | 7.32 |

Source: Field Survey, 2007

3) Education level

The education attainment can be classified into five levels such as no education, elementary, secondary, high school, college/university and more than university. Most respondents in KPP have an educational attainment at elementary, secondary and high school level of 85.69%, 6.72% and 5.69 % respectively as shown in Table 3.24.

Table 3.24 Education Level of Farmers in KPP

| Zone | Education Level (%) | | | | | |
|---|---|---|---|---|---|---|
| | Non | Elementary | Secondary | High School | College/ University | Higher than university |
| 1 | - | 85.6 | 2.9 | 8.6 | 2.9 | - |
| 2 | - | 79.5 | 12.8 | 7.7 | - | - |
| 3 | - | 93.4 | 2.2 | 2.2 | 2.2 | - |
| 4 | - | 82.5 | 7.5 | 10 | - | - |
| 5 | - | 97.2 | - | 2.8 | - | - |
| 6 | - | 73.9 | - | 21.7 | 4.4 | - |
| 7 | - | 72.1 | 11.6 | 16.3 | - | - |
| 8 | - | 77.8 | 11.1 | 11.1 | - | - |
| 9 | 2.3 | 69.8 | 27.9 | - | - | - |
| 10 | - | 85.4 | 2.4 | 9.8 | 2.4 | - |
| 11 | - | 91.7 | 5 | 3.3 | - | - |
| 12 | 1.4 | 85.5 | 11.7 | 1.4 | - | - |
| 13 | - | 97.9 | 2.1 | - | - | - |
| 14 | - | 81.3 | 12.4 | 6.3 | - | - |
| 15 | 6.7 | 93.3 | - | - | - | - |
| 16 | - | 84.8 | 6.1 | 7.6 | - | 1.5 |
| 17 | 1.6 | 81.4 | 11.9 | 5.1 | - | - |
| 18 | - | 82.8 | 8.6 | 3.4 | 5.2 | - |
| 19 | - | 86.3 | 2.3 | 9.1 | 2.3 | - |
| 20 | - | 83.8 | 5.9 | 10.3 | - | - |
| 21 | 2.2 | 86.7 | 2.2 | 8.9 | - | - |
| 22 | - | 83.7 | 6.1 | 8.2 | 2 | - |
| 23 | - | 80 | 5 | 12.5 | 2.5 | - |
| 24 | 4.2 | 91.6 | 4.2 | - | - | - |
| 25 | 1.8 | 94.7 | 3.5 | - | - | - |
| 26 | 3.6 | 82.1 | 12.5 | 1.8 | - | - |
| 27 | 1.4 | 95.8 | 1.4 | 1.4 | - | - |
| Average | 2.8 | 85.21 | 7.47 | 7.70 | 2.99 | 1.50 |

Source : Field Survey, 2007

Most respondents in PPP have an education level in the elementary and secondary by 81.93% and 17.89 % respectively as shown in Table 3.25.

Table 3.25 Education Level of Farmers in PPP

| Zone | Education Level (%) | | | | | |
|---|---|---|---|---|---|---|
| | Non | Elementary | Secondary | High School | College/ University | Higher than university |
| 1 | - | 91.18 | 8.82 | - | - | - |
| 2 | - | 81.82 | 18.18 | - | - | - |
| 3 | - | 77.14 | 22.86 | - | - | - |
| 4 | - | 97.5 | 2.5 | - | - | - |
| 5 | - | 76 | 22 | 2 | - | - |
| 6 | - | 74.29 | 25.71 | - | - | - |
| 7 | - | 92 | 8 | - | - | - |
| 8 | - | 70.69 | 29.31 | - | - | - |
| 9 | - | 92.86 | 7.14 | - | - | - |
| 10 | - | 78.13 | 21.87 | - | - | - |
| 11 | - | 69.57 | 30.43 | - | - | - |
| Average | - | 81.93 | 17.89 | - | - | - |

Source : Field Survey, 2007

4) Experience of farmers

The experience can be divided into five groups (less than 15 years, 15-26 years, 26-35 years, 36-45 years and more than 45 years). Experience was reverse varied with education attainment because farmers finished elementary school as compulsory education on elementary enactment in 1960.

Table 3.26 presents the experience of farmer in KPP. The experience of farmer in KPP was less than 15 years by 24.52%, 15-25 years by 31.80 %, 26-35 years by 25.25%, 36-45 years by 12.53% and more than 45 years by 5.90%. Table 3.27 presents the experience of farmer in PPP. The experience of farmer in PPP was less than 15 years by 28.95%, 15-25 years by 32.23 %, 26-35 years by27.66%, 36-45 years by13.17% and more than 45 years by 5.52%.

Table 3.26 Experience of Farmers in KPP

| Zone | Experience Group (%) | | | | |
|---|---|---|---|---|---|
| | <15 years | 15-25 years | 26-35 years | 36-45 years | >45 years |
| 1 | 65.5 | 26.9 | - | 3.8 | 3.8 |
| 2 | 17.9 | 23.1 | 23.1 | 33.3 | 2.6 |
| 3 | 11.1 | 24.4 | 15.6 | 31.1 | 17.8 |
| 4 | 12.5 | 32.5 | 30 | 20 | 5 |
| 5 | 13.5 | 16.2 | 40.6 | 16.2 | 13.5 |
| 6 | 30.6 | 46.3 | 15.4 | 7.7 | - |
| 7 | 100 | - | - | - | - |
| 8 | 69.7 | 15.2 | 3 | 9.1 | 3 |
| 9 | 42.3 | 19.2 | 23.2 | 3.8 | 11.5 |
| 10 | 19.2 | 34.6 | 11.5 | 11.5 | 23.2 |
| 11 | 12.3 | 22.8 | 31.5 | 21.1 | 12.3 |
| 12 | 6.7 | 42.2 | 24.4 | 20 | 6.7 |
| 13 | 2.1 | 60.4 | 37.5 | - | - |
| 14 | 40 | 5 | 35 | 20 | - |
| 15 | 31 | 31 | 38 | - | - |
| 16 | 36.2 | 20.7 | 24.1 | 6.9 | 12.1 |
| 17 | 29.1 | 38.2 | 23.6 | 9.1 | - |
| 18 | 36.8 | 21.2 | 28.9 | 10.5 | 2.6 |
| 19 | 51.2 | 11.6 | 9.3 | 20.9 | 7 |
| 20 | 35.4 | 35.4 | 20 | 9.2 | - |
| 21 | 38.5 | 30.8 | 10.3 | 12.8 | 7.6 |
| 22 | 43.6 | 35.8 | 10.3 | 10.3 | - |
| 23 | 12.5 | 33.3 | 8.4 | 12.5 | 33.3 |
| 24 | 12.3 | 51 | 36.7 | - | - |
| 25 | 8.7 | 51.7 | 27.6 | 10.3 | 1.7 |
| 26 | 8.7 | 28.1 | 43.9 | 12.3 | 7 |
| 27 | 4.3 | 41.4 | 42.9 | 11.4 | - |
| Average | 24.52 | 31.8 | 25.25 | 12.53 | 5.9 |

Source : Field Survey, 2007

Table 3.27 Experience of Farmers in PPP

| Zone | Experience Group (%) | | | | |
|---|---|---|---|---|---|
| | <15 years | 15-25 (years) | 26-35 (years) | 36-45 (years) | >45 (years) |
| 1 | 2.94 | 29.42 | 35.29 | 20.59 | 11.76 |
| 2 | 14.89 | 40.43 | 23.4 | 17.02 | 4.26 |
| 3 | 17.65 | 35.29 | 29.42 | 8.82 | 8.82 |
| 4 | - | 12.5 | 70 | 17.5 | - |
| 5 | 30 | 34 | 26 | 6 | 4 |
| 6 | 43.59 | 23.09 | 15.38 | 15.38 | 2.56 |
| 7 | 27.5 | 47.5 | 25 | - | - |
| 8 | 25.86 | 39.66 | 18.97 | 13.79 | 1.72 |
| 9 | 28.57 | 28.57 | 25 | 17.86 | - |
| 10 | 59.38 | 25 | 14.06 | 1.56 | - |
| 11 | 39.13 | 39.13 | 21.74 | - | - |
| Average | 28.95 | 32.23 | 27.66 | 13.17 | 5.52 |

Source : Field Survey, 2007

5) Land tenure

Land tenure means the actual farmer's land ownership. It is certainly a factor contribution to production cost. The land tenure in percentage can be categorized into five groups (less than 20 %, 20-40 %, 40-60 %, 60-80 % and more than 80 %).

Table 3.28 shows the land tenure of farmers in KKP. A land tenure more than 80 % of total areas is 74 % while an average land tenure of less than 20 % is 17.73 %. It indicated that farmer had own farm land of more than 80% of total areas in KPP.

Table 3.28 Land Tenure in KPP

| Zone | Land Tenure Category (%) | | | | |
|---|---|---|---|---|---|
| | <20 % | 20-40 % | 40-60 % | 60-80 % | >80 % |
| 1 | 52.63 | - | 5.26 | 5.26 | 36.85 |
| 2 | 17.39 | 8.7 | 8.7 | - | 65.21 |
| 3 | - | - | - | - | 100 |
| 4 | 5 | - | 10 | - | 85 |
| 5 | 28.13 | - | - | 3.13 | 68.74 |
| 6 | 14.29 | - | 14.29 | 28.57 | 42.85 |
| 7 | - | - | - | - | 100 |
| 8 | - | - | 12.5 | - | 87.5 |
| 9 | 23.53 | - | 5.88 | 5.88 | 64.71 |
| 10 | 50 | 16.67 | 33.33 | - | - |
| 11 | 8.11 | - | - | - | 91.89 |
| 12 | 3.64 | 3.64 | - | - | 92.72 |
| 13 | - | - | - | - | 100 |
| 14 | 58.34 | - | 8.33 | 8.33 | 25 |
| 15 | 16.67 | - | - | - | 83.33 |
| 16 | 35 | 10 | 12.5 | 2.5 | 40 |
| 17 | 61.54 | 10.26 | 15.38 | 2.56 | 10.26 |
| 18 | 12.9 | 6.45 | 3.23 | - | 77.42 |
| 19 | 40 | 5 | 5 | 10 | 40 |
| 20 | 30.61 | 2.04 | 2.04 | - | 65.31 |
| 21 | 18.52 | 7.41 | 7.41 | 7.41 | 59.25 |
| 22 | 42.86 | 9.52 | - | - | 47.62 |
| 23 | 43.75 | 12.5 | 6.25 | - | 37.5 |
| 24 | 2 | - | - | - | 98 |
| 25 | - | - | - | - | 100 |
| 26 | 7.69 | - | 3.85 | 1.92 | 86.54 |
| 27 | - | - | - | - | 100 |
| Average | 17.73 | 3 | 3.91 | 1.69 | 73.66 |

Source : Field Survey, 2007

Table 3.29 shows the land tenure in PPP. Farmers have the land tenure of more than 80 % of total areas by 31 % while the land tenure of farmers with less than 20% of the total areas is 49 %.

Table 3.29 Land Tenure in PPP

| Zone | Land Tenure Category (%) | | | | |
|---|---|---|---|---|---|
| | <20 % | 20-40 % | 40-60 % | 60-80 % | >80 % |
| 1 | 41.18 | 8.82 | 8.82 | 8.82 | 32.36 |
| 2 | 66.67 | 3.7 | 7.41 | 3.7 | 18.52 |
| 3 | 45.71 | 8.57 | 11.43 | 2.86 | 31.43 |
| 4 | 7.14 | 7.14 | - | 7.14 | 78.58 |
| 5 | 68.58 | 5.71 | 5.71 | - | 20 |
| 6 | 53.85 | 7.69 | 15.38 | - | 23.08 |
| 7 | 33.34 | 11.11 | 3.7 | 3.7 | 48.15 |
| 8 | 40 | 13.33 | 20.01 | 13.33 | 13.33 |
| 9 | 75 | - | 14.29 | 7.14 | 3.57 |
| 10 | 56.1 | 2.44 | 4.88 | 2.44 | 34.14 |
| 11 | 55 | 5 | 5 | - | 35 |
| Average | 49.32 | 7.35 | 9.66 | 6.14 | 30.74 |

Source : Field Survey, 2007

6) Crop yield data

Crop yield was ranked into five levels (i.e. very low, low, medium, high and very high) based on the annual average yield of each crop from projects. For example, a rice yield (ton/ha) of less than 4.38 is considered very low, low for 4.38 to 5.00, medium for 5.00 to 5.63, high for 5.63 to 6.25 and very high for yields exceeding 6.25. Rice yields in KPP and PPP were at the medium level since they had yields of 5.59 and 5.19 tons per hectare respectively. There was not much difference of crop yield in PPP. The score of crop yield ranking for KPP and PPP is shown in Table 3.30.

Table 3.30 Score of Crop Yield Ranking for KPP and PPP

| Type of Crops | Crop Yield Ranking | | |
|---|---|---|---|
| | Crop Yield (ton/ha) | Score | Meaning |
| Rice | <4.38 | 1 | Very Low |
| | 4.38-5.00 | 2 | Low |
| | 5.00-5.63 | 3 | Medium |
| | 5.63-6.25 | 4 | High |
| | >6.25 | 5 | Very High |
| Sugar cane | <75 | 1 | Very Low |
| | 75-93.75 | 2 | Low |
| | 93.75-106.25 | 3 | Medium |
| | 106.25-118.75 | 4 | High |
| | >118.75 | 5 | Very High |
| Finger root | <21.88 | 1 | Very Low |
| | 21.88-25.00 | 2 | Low |
| | 25.00-28.13 | 3 | Medium |
| | 28.13-31.25 | 4 | High |
| | >31.25 | 5 | Very High |
| Corn | 7.5 | 1 | Very Low |
| | 7.5-8.13 | 2 | Low |
| | 8.13-8.75 | 3 | Medium |
| | 8.75-9.38 | 4 | High |
| | >9.38 | 5 | Very High |

Source: Field Survey, 2007

7) Production cost

Production cost data involved a) farm input cost such as seed fertilizer, pesticide and herbicide, other materials, pumping, land renting b) labor cost such as land preparation, seeding and planting, harvesting cost c) transportation after harvest, e.g. when farmers travel to the rice mill for rice selling or to factory for sugar cane d) fee such as when farmers who sell sugarcane to factory pay a fee of 2 baht/ ton and pay tax 0.75 % of selling the price.

8) Farm income

The farm income means the selling price of the project. It was estimated by a total production x unit price.

9) Net farm income

The net farm income can be obtained from the farm income subtracted by the production cost. It was calculated as follows:

Net farm income = Farm income – Production cost

Where:

Farm income = Total production x unit price
Production cost = Cost included a) farm input cost b) labor cost c) other cost such as transportation d) fee (as mentioned in the production cost data)

10) B/C ratio

B/C ratio is the ratio of the total present value of benefit to the total present value of the cost. It is considered economically justified if B/C ratio is greater than one.

The cost of land renting, land preparation, broadcasting, fertilization and harvesting are expenses which affect the production cost in KPP. In some cases mutual help among the farmers can reduce the labour cost (e.g. cost for land preparation and harvesting). In zone 1, 2, and 22, the production cost is high because farmers pay high price for land renting (1000 Baht/rai/year) and they have own farm land 53% of total areas. The farmers are using more fertilizer for rice cultivation i.e. urea formula (46-0-0 and 16-20-0) amounting 25 kg/rai and 50 kg/rai, respectively. The low value of production cost in zone 24 and 26 on the other hand, is due to using manual labour instead of machine, not using fertilizer intensive e.g. urea formula (46-0-0 and 16-20-0) amounting 25 kg/rai and 25 kg/rai, respectively and low renting cost of the land (800 Baht/rai/year). Income in zone 1, 2, 24 and 26 are high because of good crop yield and the high selling prices 5700 Baht/ton and 5900 Baht/ton in wet and dry season respectively. In zone 22 income is low because of average crop yield and the low selling price of crops (5400 Baht/ton and 5700 Baht/ton in wet and dry season). The selling price depends on the moisture content of rice and the location of rice mills.

Table 3.31 Crop Yield, Production Cost and Income of Farmers in KPP

| Zone | Wet Season | | | Dry Season | | |
|---|---|---|---|---|---|---|
| | Crop Yield Ranked* | Production Cost (Baht/ha/yr) | Income (Baht/ha/yr) | Crop Yield Ranked* | Production Cost (Baht/ha/yr) | Income (Baht/ha/yr) |
| 1*[1] | 5 | 34,455±8,072 | 68,418 ±5,321 | 4 | 33,768±7,338 | 68,688 ±5,071 |
| 2*[1] | 5 | 34,931±6,310 | 64,217 ±7874 | 5 | 34,879 ±6,579 | 66,591 ±8,599 |
| 3*[1] | 3 | 25,833 ±4,636 | 63,917 ±4,243 | 3 | 25,918 ±4,762 | 64,618 ±6,660 |
| 4*[1] | 4 | 29,107 ±3,618 | 62,473 ±7599 | 4 | 29,002 ±2,405 | 69,686 ±3,229 |
| 5*[1] | 3 | 30,806 ±6,213 | 60,003 ±5,163 | 3 | 30,837 ±6,689 | 65,413 ±6,945 |
| 6*[1] | 3 | 26,407 ±7,305 | 59,925 ±9,009 | 3 | 25,738 ±7,560 | 62,488±10,610 |
| 7*[3] | 3 | 31,286±9,128 | 72,875 ±19,545 | 3 | 32,206 ±10,950 | 76,398 ±23,314 |
| 8*[5] | 3 | 40,479±9,164 | 73,336 ±15,399 | 3 | 40,731 ±9,310 | 80,211±22,006 |
| 9*[1] | 3 | 29,922 ±3,646 | 60,486 ±9,411 | 3 | 29,922 ±3,646 | 60,686 ±9,146 |
| 10*[4] | 3 | 30,671 ±7,913 | 61,326 ±9,253 | 2 | 29,737 ±7,998 | 59,491 ±14,278 |
| 11*[1] | 4 | 27,429 ±3,574 | 59,287 ±4,396 | 4 | 25,780 ±3,580 | 60,855 ±5,717 |
| 12*[4] | 4 | 26,850±4,988 | 60,324 ±8,300 | 4 | 26,508 ±4,657 | 62,512 ±7,883 |
| 13*[1] | 5 | 31,330 ±4,761 | 67,566±4,710 | 5 | 31,477 ±4,288 | 72,418 ±6,535 |
| 14*[1] | 3 | 25,881 ±5,153 | 57,538 ±8,601 | 3 | 25,524 ±3,976 | 57,125 ±6,627 |
| 15*[1] | 4 | 27,533 ±4,104 | 66,260 ±2,522 | 4 | 29,330 ±4,804 | 68,180 ±2,688 |
| 16*[4] | 3 | 24,797 ±3,949 | 60,069 ±7,819 | 3 | 25,922 ±3,315 | 60,018 ±7,326 |
| 17*[1] | 3 | 25,174 ±5,327 | 57,433 ±8,644 | 3 | 23,125 ±5,821 | 59,250 ±7,087 |
| 18*[4] | 3 | 21,525 ±5,419 | 57,8584 ±7,610 | 3 | 21,797 ±5,340 | 58,543 ±7,005 |
| 19*[2] | 5 | 51,358 ±8,051 | 91,452±13,395 | 5 | 51,358 ±8,051 | 91,452±13,395 |
| 20*[1] | 3 | 28,611 ±4,830 | 58,509 ±7,727 | 3 | 26,368 ±4,850 | 63,498 ±7,176 |
| 21*[1] | 3 | 23,717 ±5,285 | 52,793 ±5,827 | 3 | 24,161 ±5,489 | 57,115 ±6,216 |
| 22*[1] | 3 | 29,064±3,957 | 53,763 ±7,553 | 3 | 29,640 ±4,013 | 57,482 ±7,048 |
| 23*[1] | 3 | 26,046±5,319 | 59,633 ±7,464 | 3 | 25,816 ±5,703 | 63,049 ±9,532 |
| 24*[1] | 4 | 25,277 ±5,275 | 72,779 ±3,630 | 4 | 24,271 ±5,313 | 77,610 ±4,253 |
| 25*[1] | 4 | 30,080 ±8,290 | 61,567 ±6,515 | 4 | 30,091 ±8,273 | 68,508 ±5,452 |
| 26*[1] | 5 | 25,854 ±3,135 | 71,973 ±7,337 | 5 | 25,661 ±3,161 | 69,279 ±10,443 |
| 27*[1] | 5 | 34,252 ±6,078 | 68,089 ±3,055 | 5 | 34,804 ±6,044 | 76,061 ±4,284 |
| Average | 3.7±0.8 | 28,869 ±5,856 | 64,124 ±7,675 | 3.6±0.8 | 29,710 ±5,871 | 66,964 ±8,434 |

Note: 1) Data used for calculation, *[1] =rice, *[2] =sugarcane, *[3] =rice and baby corn, *[4] =rice and sugarcane, *[5] =rice, baby corn and sugarcane

: 2) 1.00 US $ = 32.4 Thai Baht

Table 3.32 Net Farm Income and Benefit/Cost Ratio in KPP

| Zone | Wet Season | | Dry Season | |
|---|---|---|---|---|
| | Net Farm Income (Baht/ha) | B/C Ratio | Net Farm Income (Baht/ha) | B/C Ratio |
| 1 | 33,963±8,460 | 1.09±0.54 | 34,919±8,190 | 1.13±0.52 |
| 2 | 29,286±8,994 | 0.89±0.38 | 31,712±7,922 | 0.95±0.36 |
| 3 | 38,084±6,356 | 1.53±0.35 | 38,700±8,105 | 1.55±0.39 |
| 4 | 33,365±8,541 | 1.17±0.34 | 40,685±3,804 | 1.42±0.20 |
| 5 | 29,197±8,180 | 1.03±0.54 | 34,567±8,628 | 1.21±0.48 |
| 6 | 33,518±5,657 | 1.36±0.50 | 36,749±4,489 | 1.51±0.40 |
| 7 | 41,589±11,137 | 1.30±0.18 | 44,192±13,539 | 1.39±0.26 |
| 8 | 32,857±10,495 | 0.84±0.27 | 39,480±16,650 | 0.98±0.34 |
| 9 | 30,565±8,844 | 1.04±0.34 | 30,765±8,600 | 1.05±0.33 |
| 10 | 30,656±8,803 | 1.09±0.48 | 29,754±9,585 | 1.04±0.38 |
| 11 | 31,858±5,332 | 1.20±0.45 | 35,075±6,272 | 1.41±0.38 |
| 12 | 33,474±7,309 | 1.31±0.49 | 36,003±7,906 | 1.42±0.51 |
| 13 | 36,237±4,727 | 1.19±0.30 | 40,941±6,133 | 1.33±0.30 |
| 14 | 31,656±7,577 | 1.28±0.45 | 31,601±7,513 | 1.29±0.45 |
| 15 | 38,727±4695 | 1.44±0.32 | 38,850±5,101 | 1.37±0.34 |
| 16 | 35,090±9,496 | 1.48±0.60 | 34,096±8,590 | 1.36±0.51 |
| 17 | 32,259±7,802 | 1.36±0.51 | 36,126±7,379 | 1.70±0.64 |
| 18 | 36,333±7,482 | 1.81±0.71 | 36,746±7,024 | 1.81±0.68 |
| 19 | 40,094±8,802 | 0.79±0.19 | 40,094±8,802 | 0.79±0.19 |
| 20 | 29,898±8,554 | 1.10±0.43 | 37,131±8,149 | 1.48±0.55 |
| 21 | 29,075±7,870 | 1.35±0.70 | 32,954±8,586 | 1.46±0.55 |
| 22 | 24,699±8,572 | 0.88±0.37 | 27,842±8,709 | 0.98±0.38 |
| 23 | 33,587±9,305 | 1.38±0.57 | 37,233±11,562 | 1.56±0.67 |
| 24 | 47,502±6,910 | 2.01±0.66 | 53,339±6,466 | 2.35±0.73 |
| 25 | 31,487±9,603 | 1.17±0.57 | 38,416±7,574 | 1.40±0.53 |
| 26 | 46,120±6,746 | 1.81±0.33 | 43,619±10,701 | 1.74±0.52 |
| 27 | 33,838±7,444 | 1.05±0.38 | 41,257±7,109 | 1.25±0.38 |
| Average | 34,360±7,915 | 1.26 ±0.43 | 37,356±8,262 | 1.37 ±0.45 |

The net farm income in zone 1 is low despite its high crop yield and selling price. The low value of the net farm income is due to the high production cost. In zone 2, the net farm income is low in spite of high crop yield. Thus the low net farm income is attributed to low selling price of crop and its high production cost.

Table 3.33 Crop Yield, Production Cost and Income of Farmers in PPP

| Zone | Wet Season | | | Dry Season | | |
|---|---|---|---|---|---|---|
| | Crop Yeild Ranked* | Production Cost (Baht/ha/yr) | Income (Baht/ha/yr) | Crop Yeild Ranked* | Production Cost (Baht/ha/yr) | Income (Baht/ha/yr) |
| 1 | 2 | 38,849 ±4,899 | 65,474 ±8,129 | 3 | 38,942 ±4,902 | 69,740 ±7,142 |
| 2 | 3 | 38,927 ±5,556 | 72,923 ±7,948 | 3 | 38,747 ±5,372 | 72,411 ±6,815 |
| 3 | 3 | 40,670 ±6,028 | 75,272 ±8,373 | 3 | 41,287 ±6,404 | 77,096 ±6,853 |
| 4 | 3 | 34,289 ±4,277 | 64,643 ±1,032 | 3 | 34,345 ±4,277 | 68,364 ±793 |
| 5 | 4 | 32,628 ±2,912 | 59,192 ±4,234 | 4 | 32,687 ±2,982 | 60,418 ±4,239 |
| 6 | 3 | 30,072 ±3,975 | 54,654 ±7,866 | 3 | 29,584 ±3,585 | 60,529 ±7,788 |
| 7 | 3 | 38,189 ±2,765 | 78,202 ±5,996 | 3 | 37,988 ±2,789 | 73,418 ±5,687 |
| 8 | 3 | 30,929 ±3,714 | 52,945 ±3,667 | 4 | 31,099 ±3,660 | 61,479 ±3,024 |
| 9 | 3 | 36,762 ±5,273 | 74,843 ±8,127 | 3 | 36,723 ±5,252 | 73,246 ±9,378 |
| 10 | 3 | 35,856 ±4,580 | 63,321 ±4,222 | 3 | 35,856 ±4,580 | 63,321 ±4,222 |
| 11 | 3 | 37,799 ±3,691 | 71,262 ±2,630 | 3 | 37,872 ±3,695 | 73,993 ±2,343 |
| Average | 3.0±0.45 | 35,906 ±3,495 | 66,611 ±8,599 | 3.18±0.40 | 35,921±3,619 | 68,547±6,103 |

Table 3.34 Crop Yield, Production Cost and Income of Farmers in PPP

| Zone | Wet Season | | | Dry Season | | |
|---|---|---|---|---|---|---|
| | Crop Yeild Ranked* | Production Cost (Baht/ha/yr) | Income (Baht/ha/yr) | Crop Yeild Ranked* | Production Cost (Baht/ha/yr) | Income (Baht/ha/yr) |
| 1 | 2 | 38,849 ±4,899 | 65,474 ±8,129 | 3 | 38,942 ±4,902 | 69,740 ±7,142 |
| 2 | 3 | 38,927 ±5,556 | 72,923 ±7,948 | 3 | 38,747 ±5,372 | 72,411 ±6,815 |
| 3 | 3 | 40,670 ±6,028 | 75,272 ±8,373 | 3 | 41,287 ±6,404 | 77,096 ±6,853 |
| 4 | 3 | 34,289 ±4,277 | 64,643 ±1,032 | 3 | 34,345 ±4,277 | 68,364 ±793 |
| 5 | 4 | 32,628 ±2,912 | 59,192 ±4,234 | 4 | 32,687 ±2,982 | 60,418 ±4,239 |
| 6 | 3 | 30,072 ±3,975 | 54,654 ±7,866 | 3 | 29,584 ±3,585 | 60,529 ±7,788 |
| 7 | 3 | 38,189 ±2,765 | 78,202 ±5,996 | 3 | 37,988 ±2,789 | 73,418 ±5,687 |
| 8 | 3 | 30,929 ±3,714 | 52,945 ±3,667 | 4 | 31,099 ±3,660 | 61,479 ±3,024 |
| 9 | 3 | 36,762 ±5,273 | 74,843 ±8,127 | 3 | 36,723 ±5,252 | 73,246 ±9,378 |
| 10 | 3 | 35,856 ±4,580 | 63,321 ±4,222 | 3 | 35,856 ±4,580 | 63,321 ±4,222 |
| 11 | 3 | 37,799 ±3,691 | 71,262 ±2,630 | 3 | 37,872 ±3,695 | 73,993 ±2,343 |
| Average | 3.0±0.45 | 35,906 ±3,495 | 66,611 ±8,599 | 3.18±0.40 | 35,921±3,619 | 68,547±6,103 |

Farmer's land ownership, application of fertilizer and chemical are factors contributing to production cost in term of land renting, fertilizer, herbicide and pesticide in PPP. In zone 1, 2, 3, 7 and 11, the production cost is high because farmers pay high price for land renting (1500 Baht/rai/year). They have own farm land less than 40% of total areas. The farmers apply more fertilizer for rice cultivation e.g. urea formula (46-0-0 and 16-20-0) amount 25 kg/rai and 50 kg/rai, respectively. However, the low value of production cost in zone 5, 6 and 8 is due to using low fertilizer and cheap land renting (800 Baht/rai/year). Income in zone 2, 3, 7, 9 and 11 are high because of the high selling prices 5600 Baht/ton and 5700 Baht/ton in wet and dry season respectively. In zone 5, 6 and 8, income is low because of the low selling price of crops (5300 Baht/ton and 5500 Baht/ton in wet and dry season) despite of good crop yield.

Table 3.35 Net Farm Income and Benefit/Cost Ratio in PPP

| Zone | Wet Season | | Dry Season | |
|---|---|---|---|---|
| | Net Farm Income (Baht/ha) | B/C Ratio | Net Farm Income (Baht/ha) | B/C Ratio |
| 1 | 26,625±8,192 | 0.71±0.26 | 30,798±7,783 | 0.81±0.26 |
| 2 | 33,996±9,176 | 0.90±0.31 | 33,664±8,375 | 0.90±0.29 |
| 3 | 34,602±7,278 | 0.87±0.24 | 35,809±6,344 | 0.90±0.24 |
| 4 | 30,354±4,664 | 0.78±0.19 | 34,019±4,421 | 1.02±0.24 |
| 5 | 26,564±4,358 | 0.83±0.19 | 27,731±5,174 | 0.86±0.23 |
| 6 | 24,582±9,257 | 0.85±0.42 | 30,945±7,582 | 1.06±0.30 |
| 7 | 40,014±6,075 | 1.06±0.20 | 35,430±5,712 | 0.94±0.19 |
| 8 | 22,016±3,650 | 0.73±0.16 | 30,380±3,990 | 1.00±0.21 |
| 9 | 38,081±9,683 | 1.08±0.40 | 36,522±10,729 | 1.04±0.41 |
| 10 | 27,465±6,391 | 0.79±0.25 | 27,465±6,319 | 0.79±0.25 |
| 11 | 33,463±4,983 | 0.90±0.21 | 36,121±4,749 | 0.97±0.21 |
| Average | 30,706±5,763 | 0.86 ±0.12 | 32,626±3,320 | 0.94 ±0.09 |

The net farm income in zone 1 is low despite good crop yield and high selling price. Thus the low value of the net farm income is due to high production costs. In zone 5 and 8, the net farm income is low in spite of low production costs and good crop yield. The low net farm income is attributed to the low selling price of crops. Net farm income in zone 2, 3, 7, 9 and 11 on the other hand, are high despite of high production costs. The high value of net farm income is due to high selling price and good crop yield.

#### 3.4.2.2 Awareness on irrigation water use

Awareness on irrigation water use explains farmers are aware on how to use water wisely and increase water use efficiency. It can be classified into five levels i.e. 1=worst, 2=bad, 3=undecided, 4=good and 5=very good. The results indicated that the awareness on irrigation water use of farmers from both KPP and PPP were good as shown in Table D-2 and D-6 respectively.

#### 3.4.2.3 Water user conflict occurrence

Water user conflict is an important indicator of water management in terms of water delivery. Water should be possible for each farmer especially downstream farmer when water scarcity has been the source of conflict. This factor was classified into five ranks i.e. 1=never, 2=rarely, 3=occasionally, 4=frequently and 5=more than 5 times as shown in Table D-2 and D-6. The result indicated that the conflict of farmers was noted as rarely and never from KPP and PPP respectively.

### 3.4.3 Environment category

#### 3.4.3.1 Soil quality

1) Soil pH

Soil pH is a measure of degree of acidity and alkalinity of soil that affects the plant growth. Soil is neutral if pH value is 7.0. A value lower than the mentioned figure indicates that the soil is acid and a value higher than 7.0 indicates that the soil is of alkalinity level. Soil pH value from 5.5-7.0 (medium acid to neutrality) is ideal for crop plantation.

Based on Im-Erb (1991) soil pH was divided into five classes i.e. 1=basic, 2=slightly acidic, 3=moderately acidic, 4=strongly acidic and 5=very strongly acidic. If the soil pH is more than 7 then the soil pH is considered to be basic. If the soil pH is between 6-7, 5.5-6, 4.5-5.5 and less than 4.5 then it is considered to be slightly acidic, moderately acidic, strongly acidic and very strongly acidic respectively. The result of soil pH for KPP is presented in Table 3.36. The result showed that only zone 17 has a soil pH value of 4.7. It can be indicated that soil is strongly acidic and this zone requires more lime application during land preparation.

2) Soil electrical conductivity (EC)

Electric conductivity (EC) is the most common measure of soil salinity and indicates the ability of an aqueous solution to carry an electric current. Soil salinity is a soil property that defines the amount of soluble salt in the soil. Based on Richards (1954) salinity of soil can be interpreted as shown in Table 3.36.

Table 3.36 Salinity Level

| Electric Conductivity Value (dS/m) | Salinity Level | Interpretation | Score |
|---|---|---|---|
| 0-2 | No salinity | Little no effect on the growth and yield of plants | 5 |
| >2-4 | Salinity | Affects only very sensitive plants | 4 |
| >4-8 | Medium salinity | Affects many plants | 3 |
| >8-16 | Strongly salinity | Affects tolerant plants | 2 |
| >16 | Very strongly salinity | Affects even very tolerant plants | 1 |

Source: Richards (1954)

Soils electrical conductivity in KPP was less than 2 dS/m. It indicated that there was no problem on salinity in this project. The results of soil characteristic are presented in Table 3.37.

The results of soil pH for PPP showed a uniform score of 4. This result showed that its soil was strongly acidic and this area requires more lime application during land preparation. However, the result of soil pH for PPP might be erroneous because of a possible contamination during the soil sampling. On the other hand, there was no problem on salinity in this project. The results of soil characteristic are presented in Table 3.38.

Table 3.37 Soil pH and Electrical Conductivity of Soil for KPP

| Zone | Soil Characteristic | | | |
|---|---|---|---|---|
| | Soil pH | Score | Electrical Conductivity | Score |
| 1 | 6.54 | 2 | 0.09 | 5 |
| 2 | 6.68 | 2 | 0.13 | 5 |
| 3 | 6.76 | 2 | 0.14 | 5 |
| 4 | 6.01 | 2 | 0.16 | 5 |
| 5 | 5.72 | 3 | 0.09 | 5 |
| 6 | 5.54 | 3 | 0.28 | 5 |
| 7 | 6.21 | 2 | 0.10 | 5 |
| 8 | 6.65 | 2 | 0.19 | 5 |
| 9 | 6.78 | 2 | 0.23 | 5 |
| 10 | 6.59 | 2 | 0.42 | 5 |
| 11 | 6.71 | 2 | 0.42 | 5 |
| 12 | 6.64 | 2 | 0.29 | 5 |
| 13 | 6.17 | 2 | 0.44 | 5 |
| 14 | 5.92 | 3 | 0.45 | 5 |
| 15 | 5.78 | 3 | 0.50 | 5 |
| 16 | 6.10 | 2 | 0.31 | 5 |
| 17 | 4.70 | 4 | 0.99 | 5 |
| 18 | 6.08 | 2 | 0.36 | 5 |
| 19 | 6.16 | 2 | 0.33 | 5 |
| 20 | 6.47 | 2 | 0.74 | 5 |
| 21 | 5.83 | 3 | 0.80 | 5 |
| 22 | 6.40 | 2 | 0.38 | 5 |
| 23 | 6.23 | 2 | 0.27 | 5 |
| 24 | 6.13 | 2 | 0.47 | 5 |
| 25 | 6.10 | 2 | 0.43 | 5 |
| 26 | 5.73 | 3 | 0.83 | 5 |
| 27 | 5.80 | 3 | 0.73 | 5 |

Table 3.38 Soil pH and Electrical Conductivity of Soil for PPP

| Zone | Soil Characteristic | | | |
|---|---|---|---|---|
| | Soil pH | Score | Electrical Conductivity | Score |
| 1 | 5.35 | 4 | 0.18 | 5 |
| 2 | 5.50 | 4 | 0.50 | 5 |
| 3 | 5.18 | 4 | 0.35 | 5 |
| 4 | 5.13 | 4 | 0.31 | 5 |
| 5 | 5.05 | 4 | 0.33 | 5 |
| 6 | 4.57 | 4 | 0.48 | 5 |
| 7 | 5.05 | 4 | 0.47 | 5 |
| 8 | 4.85 | 4 | 0.24 | 5 |
| 9 | 4.80 | 4 | 0.38 | 5 |
| 10 | 4.83 | 4 | 0.50 | 5 |
| 11 | 5.17 | 4 | 0.58 | 5 |

### 3.4.3.2 Water quality

The important factors to consider for environment factor in irrigation water quality are; electrical conductivity (EC), total dissolved solids (TDS), pH and dissolved oxygen (DO).

1) Electrical conductivity (EC)

Electrical Conductivity (EC) is a measure of the water salinity or the total salt content of water based on the flow of electrical current through the sample. EC is measured in unit deciSeimens per meter (dS/m).

2) Total dissolved solid (TDS)

Total dissolved solid (TDS) represents the total amount of salts in the water. Total dissolved solid (TDS) is reported in milligrams per liter (mg/l), parts per million (ppm) or parts per thousand (ppt). The TDS concentration can be obtained by multiplying the conductivity value with a factor which is empirically determined.

3) Acidity/Alkalinity (pH)

pH is a measure of the acidity or alkalinity of water. The pH scale ranges from 1 to 14, if pH 1 to 7 is acid, 7 to 14 is alkaline and pH 7.0 is neutral. The normal range for irrigation water is from pH 6.5 to pH 8.0 where crops have done well in this range.

Table 3.39 presents classification of water quality in different scores for each quality level using guidelines of Arnold et al. (2007) for interpretation of irrigation water quality.

Table 3.39 Classification of Water Quality for Irrigation Water

| Electrical Conductivity (EC) (dS/m) | TDS (ppm) | pH | Quality | Score |
|---|---|---|---|---|
| < 0.25 | <175 | <6.5 | Excellent | 5 |
| 0.25-0.75 | 175-525 | 6.5-6.8 | Good | 4 |
| 0.75-2.00 | 525-1400 | 6.8-7.0 | Permission | 3 |
| 2.00-3.00 | 1400-2100 | 7.0-8.0 | Doubtful | 2 |
| >3.00 | >2100 | >8.0 | Unsuitable | 1 |

Source: Arnold et al. (2007)

4) Dissolved oxygen (DO)

Dissolved Oxygen (DO) indicated the amount of oxygen dissolved in a body of water. In this study DO was classified into four classes such as a much deteriorated, deteriorated, fair, and good. Table 3.40 presents the classification of dissolved oxygen (DO) using the guidelines of Pollution Control Department (PCD, 2007) to interpret DO factor and make a score for each quality level.

Table 3.40 Classification of Dissolved Oxygen (DO) Quality

| (Dissolved Oxygen) (mg/l) | Quality | Score |
|---|---|---|
| <2 | Very deteriorated | 1 |
| 2-4 | Deteriorated | 2 |
| 4-6 | Fair | 3 |
| >6 | Good | 4 |

Source: PCD (2007)

The values and score of irrigation water at KPP in wet season and dry season are shown in Table 3.41 and Table 3.42. The values of water quality parameters are illustrated in Figure B-23 and Figure B-24. Ec, TDS and DO of irrigation water quality were very constant. For Ec and TDS of irrigation water were excellent, and DO of irrigation water was good. The pH of irrigation water fluctuate but within the permitted standard of RID.

Table 3.41 Parameters and Score of Irrigation Water in KPP (Wet Season)

| Zone | Parameters of Irrigation Water | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | pH | Score | EC (dS/m) | Score | TDS(mg/l) | Score | DO(mg/l) | Score |
| 1 | 7.29 | 2 | 0.23 | 5 | 114.33 | 5 | 6.97 | 4 |
| 2 | 7.34 | 2 | 0.23 | 5 | 111.28 | 5 | 6.70 | 4 |
| 3 | 7.81 | 2 | 0.23 | 5 | 109.95 | 5 | 6.73 | 4 |
| 4 | 7.39 | 2 | 0.23 | 5 | 111.25 | 5 | 6.73 | 4 |
| 5 | 7.80 | 2 | 0.23 | 5 | 109.28 | 5 | 6.79 | 4 |
| 6 | 7.24 | 2 | 0.23 | 5 | 108.58 | 5 | 7.13 | 4 |
| 7 | 7.75 | 2 | 0.23 | 5 | 109.20 | 5 | 6.85 | 4 |
| 8 | 7.51 | 2 | 0.22 | 5 | 107.77 | 5 | 7.20 | 4 |
| 9 | 7.66 | 2 | 0.23 | 5 | 109.60 | 5 | 7.18 | 4 |
| 10 | 7.22 | 2 | 0.22 | 5 | 111.83 | 5 | 7.47 | 4 |
| 11 | 7.06 | 2 | 0.22 | 5 | 107.09 | 5 | 7.22 | 4 |
| 12 | 6.97 | 3 | 0.23 | 5 | 108.27 | 5 | 7.20 | 4 |
| 13 | 7.02 | 2 | 0.22 | 5 | 108.53 | 5 | 7.50 | 4 |
| 14 | 6.57 | 4 | 0.22 | 5 | 109.70 | 5 | 7.07 | 4 |
| 15 | 6.57 | 4 | 0.23 | 5 | 109.03 | 5 | 7.23 | 4 |
| 16 | 6.51 | 4 | 0.23 | 5 | 109.85 | 5 | 7.15 | 4 |
| 17 | 6.99 | 3 | 0.23 | 5 | 112.05 | 5 | 7.47 | 4 |
| 18 | 7.02 | 2 | 0.23 | 5 | 109.93 | 5 | 7.17 | 4 |
| 19 | 6.78 | 4 | 0.23 | 5 | 115.63 | 5 | 7.23 | 4 |
| 20 | 6.95 | 3 | 0.23 | 5 | 109.63 | 5 | 7.12 | 4 |
| 21 | 7.19 | 2 | 0.24 | 5 | 117.60 | 5 | 6.87 | 4 |
| 22 | 6.80 | 4 | 0.22 | 5 | 114.48 | 5 | 7.32 | 4 |
| 23 | 6.80 | 3 | 0.23 | 5 | 114.18 | 5 | 7.31 | 4 |
| 24 | 7.11 | 2 | 0.22 | 5 | 107.13 | 5 | 7.18 | 4 |
| 25 | 7.22 | 2 | 0.22 | 5 | 108.13 | 5 | 7.24 | 4 |
| 26 | 7.21 | 2 | 0.24 | 5 | 107.40 | 5 | 7.02 | 4 |
| 27 | 7.48 | 2 | 0.22 | 5 | 108.60 | 5 | 7.28 | 4 |

Table 3.42  Parameters and Score of Irrigation Water in KPP (Dry Season)

| Zone | Parameters of Irrigation Water | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | pH | Score | EC (dS/m) | Score | TDS(mg/l) | Score | DO(mg/l) | Score |
| 1 | 7.89 | 2 | 0.21 | 5 | 92.25 | 5 | 7.15 | 4 |
| 2 | 7.90 | 2 | 0.19 | 5 | 91.92 | 5 | 7.96 | 4 |
| 3 | 8.10 | 1 | 0.19 | 5 | 91.63 | 5 | 7.91 | 4 |
| 4 | 7.85 | 2 | 0.19 | 5 | 92.05 | 5 | 8.00 | 4 |
| 5 | 8.04 | 1 | 0.20 | 5 | 94.58 | 5 | 7.21 | 4 |
| 6 | 8.05 | 1 | 0.20 | 5 | 96.22 | 5 | 7.28 | 4 |
| 7 | 7.81 | 2 | 0.19 | 5 | 93.00 | 5 | 8.08 | 4 |
| 8 | 8.01 | 1 | 0.19 | 5 | 90.95 | 5 | 7.85 | 4 |
| 9 | 8.05 | 1 | 0.19 | 5 | 91.00 | 5 | 7.34 | 4 |
| 10 | 7.17 | 2 | 0.18 | 5 | 87.75 | 5 | 7.61 | 4 |
| 11 | 7.95 | 2 | 0.19 | 5 | 91.81 | 5 | 7.67 | 4 |
| 12 | 7.43 | 2 | 0.18 | 5 | 88.57 | 5 | 7.49 | 4 |
| 13 | 7.89 | 2 | 0.19 | 5 | 90.58 | 5 | 7.66 | 4 |
| 14 | 6.69 | 4 | 0.18 | 5 | 87.55 | 5 | 7.73 | 4 |
| 15 | 7.75 | 2 | 0.21 | 5 | 98.40 | 5 | 7.78 | 4 |
| 16 | 7.71 | 2 | 0.18 | 5 | 86.60 | 5 | 7.74 | 4 |
| 17 | 7.29 | 2 | 0.19 | 5 | 92.15 | 5 | 7.83 | 4 |
| 18 | 7.07 | 2 | 0.18 | 5 | 87.35 | 5 | 7.71 | 4 |
| 19 | 6.92 | 3 | 0.18 | 5 | 85.90 | 5 | 7.45 | 4 |
| 20 | 7.07 | 2 | 0.19 | 5 | 90.00 | 5 | 7.27 | 4 |
| 21 | 7.03 | 2 | 0.19 | 5 | 91.10 | 5 | 6.98 | 4 |
| 22 | 6.91 | 3 | 0.18 | 5 | 88.28 | 5 | 7.31 | 4 |
| 23 | 6.83 | 3 | 0.26 | 4 | 95.75 | 5 | 7.41 | 4 |
| 24 | 7.93 | 2 | 0.19 | 5 | 88.43 | 5 | 7.91 | 4 |
| 25 | 8.00 | 2 | 0.19 | 5 | 91.33 | 5 | 7.68 | 4 |
| 26 | 7.98 | 2 | 0.19 | 5 | 90.38 | 5 | 7.28 | 4 |
| 27 | 8.03 | 1 | 0.19 | 5 | 91.70 | 5 | 7.40 | 4 |

The values and score of irrigation water PPP in wet and dry season are shown in Table 3.43 and Table 3.44. The table shows that all parameter values are higher than the irrigation water quality standard for agriculture except the DO value at Bangplama regulator (station 22) and Drainage canal Suphan 3-5R (Station 19) as shown in Table A-3 and Table A-4. Bangplama regulator is the last regulator control flow before diversion to Tha Chin River.

The values of water quality parameters are illustrated in Figure B-25 and Figure B-26. The Ec, TDS and DO of irrigation water quality were very constant. The Ec and TDS of irrigation water were excellent, DO of irrigation water was good, whereas pH irrigation water fluctuate but within the permitted standard of RID as shown in Table A-5. The score of irrigation water at PPP was similar to the score on irrigation water at KPP.

Table 3.43 Score of Irrigation Water Quality Parameters for PPP in Wet season

| Zone | Parameters of Irrigation Water Quality | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | pH | Score | EC (dS/m) | Score | TDS(mg/l) | Score | DO(mg/l) | Score |
| 1 | 7.29 | 2 | 0.23 | 5 | 114.33 | 5 | 6.97 | 4 |
| 2 | 7.34 | 2 | 0.23 | 5 | 111.28 | 5 | 6.70 | 4 |
| 3 | 7.81 | 2 | 0.23 | 5 | 109.95 | 5 | 6.73 | 4 |
| 4 | 7.39 | 2 | 0.23 | 5 | 111.25 | 5 | 6.73 | 4 |
| 5 | 7.80 | 2 | 0.23 | 5 | 109.28 | 5 | 6.79 | 4 |
| 6 | 7.24 | 2 | 0.23 | 5 | 108.58 | 5 | 7.13 | 4 |
| 7 | 7.75 | 2 | 0.23 | 5 | 109.20 | 5 | 6.85 | 4 |
| 8 | 7.51 | 2 | 0.22 | 5 | 107.77 | 5 | 7.20 | 4 |
| 9 | 7.66 | 2 | 0.23 | 5 | 109.60 | 5 | 7.18 | 4 |
| 10 | 7.22 | 2 | 0.22 | 5 | 111.83 | 5 | 7.47 | 4 |
| 11 | 7.06 | 2 | 0.22 | 5 | 107.09 | 5 | 7.22 | 4 |

Table 3.44 Score of Irrigation Water Quality Parameters for PPP in Dry season

| Zone | Parameters of Irrigation Water Quality | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | pH | Score | EC (dS/m) | Score | TDS(mg/l) | Score | DO(mg/l) | Score |
| 1 | 7.89 | 2 | 0.21 | 5 | 92.25 | 5 | 7.15 | 4 |
| 2 | 7.90 | 2 | 0.19 | 5 | 91.92 | 5 | 7.96 | 4 |
| 3 | 8.10 | 1 | 0.19 | 5 | 91.63 | 5 | 7.91 | 4 |
| 4 | 7.85 | 2 | 0.19 | 5 | 92.05 | 5 | 8.00 | 4 |
| 5 | 8.04 | 1 | 0.20 | 5 | 94.58 | 5 | 7.21 | 4 |
| 6 | 8.05 | 1 | 0.20 | 5 | 96.22 | 5 | 7.28 | 4 |
| 7 | 7.81 | 2 | 0.19 | 5 | 93.00 | 5 | 8.08 | 4 |
| 8 | 8.01 | 1 | 0.19 | 5 | 90.95 | 5 | 7.85 | 4 |
| 9 | 8.05 | 1 | 0.19 | 5 | 91.00 | 5 | 7.34 | 4 |
| 10 | 7.17 | 2 | 0.18 | 5 | 87.75 | 5 | 7.61 | 4 |
| 11 | 7.95 | 2 | 0.19 | 5 | 91.81 | 5 | 7.67 | 4 |

### 3.4.3.3 Drained water quality

Average parameter values were computed using weekly data starting from January to December 2007. These values were distributed into wet and dry season. All average parameter values of two projects were higher than the water quality standard for drained water as given in Table A-18. The average parameters value of water quality of KPP and PPP are shown in Table A-14 to A-15 and Table A-16 to A-17 respectively.

### 3.4.3.4 Perception of drained water quality

Perception of drained water quality means the perception of farmer on the quality of used water for agriculture with regards to the drainage of water quality flow from the field. The awareness of farmers on water drainage quality are classified into five levels i.e.1=worst, 2=bad, 3=undecided, 4=good and 5=very good. The perception of drained water quality of farmers in KPP and PPP are shown in Table D-3 and D-7 respectively. The results found that the farmers in the KPP are concerned on the quality of used water than the farmers in the PPP.

#### 3.4.3.5 Perception of soil quality

Perception of soil quality means the perception of farmer on the soil conservation and fertilizer application. The farmers' awareness to soil quality is classified into five levels i.e. 1= worst, 2=bad, 3=undecided, 4=good and 5=very good. The perception of soil quality of farmers in KPP and PPP are shown in Table D-3 and D-7 respectively. The results found that the farmers in the KPP have more concern on soil quality than the farmers in the PPP.

#### 3.4.3.6 Crop residue treatment method

Type of crop residue treatment is an indicator to check the crop residue treatment after farmers' harvest. It is classified into four groups i.e. 1=mainly for burning, 2=mainly to return to the soil, 3=mainly for forage and 4=others. The type of crop residue treatment of KPP and PPP are shown in Table D-3 and D-7 respectively. The results indicated that the crop residue treatment that returns to the soil was found in KPP whereas burning was found in PPP.

### 3.4.4 Institutional category

The questionnaires were used to determine the farmer's degree of satisfaction on irrigation water delivery. Details such as the degree of satisfaction on the adequacy of water distribution to individual farms, matching of farm operations with RID water delivery, reliability of continuous flow during irrigation period, degree of satisfaction on institutional organization and information about the farmer's willingness to pay for their irrigation water were also included in the questionnaires. A five-point Likert scale was used for the optimization scale. Each item in this scale ranged from 1 (strongly disagree) to 5 (strongly agree). Reliability of questionnaires was tested using Cronbach's alpha coefficient method (Pallant, 2005). Additional information about the institutional indicators used in this study is described below:

#### 3.4.4.1 Manpower (number of staff and work load of staff)

Work load is the ratio of number of staff (full time equivalent) per responsible irrigated area. It defines the ability of the RID staff (zone man, gate tender and canal keeper) to take care of the irrigated area.

Each zone has only one zoneman responsible for the irrigated area apart from the gate tender who is responsible gate regulator and canal operator or canal keeper who is responsible canal. Table 3.45 presents work load of staff, the work load in zone 7 is the highest and the lowest at zone 11. The average of work load in KPP is 0.0030 person/ hectare.

Table 3.45 Work Load of Staff in KPP

| Zone | No. of Staff | Irrigated Area (ha) | Work Load (person / ha) |
|---|---|---|---|
| 1 | 5 | 802 | 0.0062 |
| 2 | 4 | 1,027 | 0.0039 |
| 3 | 4 | 1,544 | 0.0026 |
| 4 | 5 | 1,680 | 0.0030 |
| 5 | 4 | 1,566 | 0.0026 |
| 6 | 4 | 1,232 | 0.0032 |
| 7 | 8 | 1,109 | 0.0072 |
| 8 | 5 | 1,440 | 0.0035 |
| 9 | 3 | 772 | 0.0039 |
| 10 | 8 | 2,147 | 0.0037 |
| 11 | 3 | 3,099 | 0.0010 |
| 12 | 7 | 2,245 | 0.0031 |
| 13 | 5 | 1,654 | 0.0030 |
| 14 | 3 | 819 | 0.0037 |
| 15 | 5 | 1,723 | 0.0029 |
| 16 | 3 | 1,192 | 0.0025 |
| 17 | 3 | 1,126 | 0.0027 |
| 18 | 3 | 1,313 | 0.0023 |
| 19 | 3 | 2,215 | 0.0014 |
| 20 | 3 | 1,180 | 0.0025 |
| 21 | 4 | 1,479 | 0.0027 |
| 22 | 2 | 1,853 | 0.0011 |
| 23 | 4 | 1,218 | 0.0033 |
| 24 | 4 | 2,178 | 0.0018 |
| 25 | 5 | 1,962 | 0.0025 |
| 26 | 2 | 1,300 | 0.0015 |
| 27 | 2 | 572 | 0.0035 |
| Avg. | 4 | 1,498 | 0.0030 |

Table 3.46 presents the work load of staff in PPP. The work load in zone 2 and zone 3 are the highest and the lowest at zone 10. The average work load in PPP is 0.00068 (person/ hectare).

Table 3.46 Work Load of Staff in PPP

| Zone | No. of Staff | Irrigated Area (ha) | Work Load (person / ha) |
|---|---|---|---|
| 1 | 3 | 1,213 | 0.0025 |
| 2 | 8 | 2,070 | 0.0039 |
| 3 | 2 | 2,058 | 0.0010 |
| 4 | 2 | 1,078 | 0.0019 |
| 5 | 3 | 2,004 | 0.0015 |
| 6 | 1 | 1,538 | 0.0007 |
| 7 | 2 | 1,751 | 0.0011 |
| 8 | 5 | 1,564 | 0.0032 |
| 9 | 4 | 1,884 | 0.0021 |
| 10 | 1 | 994 | 0.0010 |
| 11 | 1 | 1,096 | 0.0009 |
| Avg. | 3 | 1,568 | 0.0019 |

#### 3.4.4.2 Degree of satisfaction of farmer on water delivery

Questionnaires in the form of RID were designed to interview farmers to get information about the degree of satisfaction on irrigation water delivery. Tables D-4 and D-8 show the degree of satisfaction on these processes for KPP and PPP. The processes of irrigation water delivery are as follows;

1) cultivated areas survey by WUG before irrigation season
2) planning of water delivery schedule by RID staffs and WUG
3) listen to the opinion of WUG listening RID staffs
4) announcement of the irrigation schedule to all WUG
5) accountability of timeliness and fairness of water distribution

#### 3.4.4.3 Satisfaction on adequacy of water distribution

Satisfaction on adequacy of water distribution is the satisfaction degree of farmers on adequacy of amount of water distribution to individual farms during the irrigation season. This indicator indicates that how water is delivered adequately and equitably during the period and what is the satisfaction degree of farmers receiving an equivalent share of water, in accordance to their actual areas. The results indicated that satisfaction degree of farmer on the adequacy of amount of water distribution of farmers from KPP and PPP was moderately satisfied as shown in Table D-4 and D-8 respectively.

#### 3.4.4.4 Matching of farm operations with RID water delivery

Matching of farm operations with RID water delivery means satisfaction degree of farmers on the match between farm operations and water delivery from KPP. Irrigation scheduling helps in conserving water and making decisions as to the timing and quantity of water supply commensurate with crop needs. The results indicated that satisfaction degree of farmers on the match between farm operations and water delivery from KPP and PPP were leveled at high satisfied as shown in Table D-4 and D-8 respectively.

#### 3.4.4.5 Reliability of continuous flow

Reliability of continuous flow is satisfaction degree of farmer on the reliability of continuous flow during the irrigation period. The reliability here means adequacy of water to the crop diverted at the appropriate time. Furthermore, it should be possible for each farmer to know in advance when and how much water each of them can divert to their plots without the constraints of time and the diverted amount of water. The results indicated that satisfaction degree of farmer on the reliability of continuous flow during the irrigation period of farmers from KPP and PPP were on a level of high satisfaction as shown in Table D-4 and D-8 respectively.

#### 3.4.4.6 Satisfaction on water delivery planning process

Satisfaction on water delivery planning process indicates the satisfaction degree of farmers on the process of water delivery planning involving cultivated areas survey by WUG before irrigation season, planning of water delivery schedule by RID staffs and WUG, meeting between Chief of WUG and WUG for schedule planning agreement, listen to the opinion of WUG listening RID staffs, announcement of the irrigation schedule to all WUG and accountability of timeliness and fairness of water distribution. The results indicated that satisfaction level on water delivery planning process in KPP and PPP were moderately satisfied as shown in Table D-4 and D-8 respectively.

#### 3.4.4.7 Willingness to pay

Willingness to pay means the willingness of farmer to pay for irrigation water fee. This indicator can be used to explain their attitude towards value of water and maintenance expense. Moreover, fee collection rate was not concern in there. However, farmers in the KPP and PPP have never paid for any irrigation service except in zone 9 of KPP where farmers pay an irrigation fee of 50 Baht/rai/household. The results indicated that there was higher level of willingness to pay in KPP than in PPP as shown in Table D-4 and D-8 respectively. Based on survey, farmers are willing to pay for irrigation fee at average of 25 and 20 Baht/rai/year for KPP and PPP respectively.

#### 3.4.4.8 Communication between farmer and RID staff

Communication methods explain how farmers communicate with RID staff for getting the information (as with startup and closure of the operation system, meeting of WUA and training). These were categorized into five classes i.e. 1=telephone, 2=letter, 3=WUA, 4=personal and 5=other (specify). The result indicated that the information reach farmers by WUA in KPP whereas communication through telephone was more popular in PPP as shown in Table D-4 and D-8 respectively.

## 3.5 Identification of Factors and Indicators Using PCA

### 3.5.1 Using PCA approach

There are three main steps using the principal component analysis approach as follows:

Step 1 is the assessment of the suitability of the data for factor analysis. There are two main issues to consider in determining whether a particular data set is suitable for factor analysis: sample size and the strength of the relationship among the variables. Two statistical measures were generated by SPSS to help assess the factorability of the data namely; Bartlett’s test of sphericity (Bartlett, 1954) and the Kaiser Mayer Olkin (KMO) measure of sampling adequacy (Kaiser, 1974). The Bartlett’s test of sphericity should be significant ($p<0.05$) for the factor analysis to be considered appropriate. KMO should be greater than 0.5 that is recommendation accepting value then the result of PCA can be considered acceptable. Furthermore, KMO values between 0.5 - 0.7 are mediocre, KMO values between 0.7 – 0.8 are good, KMO values between 0.8-0.9 are great and values above 0.9 are superb (Field, 2005). Inspection of the correlation matrix for evidence of coefficients greater than 0.3, if few correlation above this level are found, then factor analysis may not be appropriate (Pallant, 2005).

Step 2 is factor extraction using principal component analysis approach. Tabachnick and Fidell (2001) recommend Kaiser’s criterion techniques to assist in the decision concerning the number of factors to be retained. Factors with an eigenvalue of 1.0 or more are retained for further investigation.

Step 3 is factor rotation and interpretation. The most commonly used orthogonal approach is the varimax method (Kaiser, 1958) which attempts to minimize the number of variables that have high loadings on each factor.

### 3.5.2 Determination of dominant factors affecting irrigation system

In this study, Principal component analysis (PCA) may help in identifying the factors presenting the most important variability in the sample, and then, explaining the most part of the total variability which represent physical, socio-economic, institutional and environmental parameters. The analysis involved a sequence of logical steps, starting with the initial selection of factors to the determination of key factors that is best represented from the physical, socio-economic, institutional, and environmental parameters. The sequences of main steps are as follows:

1) Selection of a set of physical, socio-economic, institutional and environmental indicators for the study area are shown in Table 3.3.

2) T-test was used to test normality of data distribution and Cronbach's alpha was used to test the reliability of questionnaire. Moreover, bivariate analysis was used to test the correlation of data (for more details see Table E-5 to E-8).

3) PCA was used to find out the principal components (PCs) as the best representative factors or indicators (key factors). It will be assumed that PCs with high variance (eigenvalues) best represent system indicators. Therefore, only PCs with eigenvalues more than 1 are used for further analysis (Pallant, 2005). Eigenvalues are the amount of variance explained by each factor, in this case "physical, socio-economic, institutional and environmental indicators/attributes".

PCs were then used to group the initially identified factors into statistical factors based on their correlation structure. The correlation structure was analysed using bivariate analysis. Each variable (i.e. infrastructure and socio-economic attribute) in the PCs received a weight or factor loading (eigenvectors) that represented its contribution to the PCs. Retained variables which have high factor loading for each selected PCs were then identified. As suggested by Andrews et al. (2002), only the highly weighted variables from each PCs were retained in the data set. Highly weighted variables were defined as those within 10% of the highest factor loading. When more than one variable was retained within PCs, their correlation significance will be observed. If the weighted variables were not correlated (i.e., $r < 0.60$), then each will be considered important and will be retained in the PCs. If the variables were significantly correlated, one of the variables can be considered redundant and; therefore, eliminated from the PC. Among the significantly correlated variables within a PCs, the variable with the highest sum of correlation coefficients will be chosen for the PCs (Andrews et al., 2002). The selected variables are then defined as the key factors affecting irrigation system.

### 3.5.3 Determination of irrigation sustainability index (ISI)

1) To select the dominant indicators, principal component analysis (PCA) was used to identify irrigation sustainability indicators based on sustainability indicators selected as shown in Table 3.4.

2) T-test was used to test for the normality of data distribution and Cronbach's alpha was used to test the reliability of the questionnaire (for more details see Table E-5 to E-8).
3) PCA was used to find out the principal components (PCs) as the best representative indicators or key indicators.

### 3.5.4 Developing irrigation sustainability index (ISI)

To develop the irrigation sustainability index (ISI), principal components (PCs) for a data set are defined as linear combinations of the variables that account for maximum variance within the set. ISI was then developed using the score of key indicators which were obtained earlier by PCA and combined linearly after multiplying with respective weights of PCs. According to Andrews et al. (2002) modified soil quality index (SQI) formula. Halim et al. (2006) constructed the erosion hazard index (EHI) equation based on (SQI). The ISI formula was also constructed as follows:

$$ISI = \sum_{i=1}^{n} W_i * Y_{(x)i} \tag{3.5}$$

Where

W =The PC weighting factor
Y=the score of key indicator
X = Key indicator

The three steps are;

1) The PC weighting factor (W) is the weight of each PC which determined by the percentage of variance in the PC divided by the total percentage of variance of all PCs.
2) Scaling, Scoring and conversion of key indicators into a 0 to 1 scale. To transform the measured indicator values into performance based scored using the modified two equations proposed by Diack and Stott (2001) cited in Halim et al. (2006), the equations were:

Y = (z-s)/(1.1t-s) for "more is better contribution for irrigation sustainability" (3.6)
Y = 1- ((z-s)/1.1t-s)) for "less is better contribution for irrigation sustainability" (3.7)

Where
Y = Score of key indicator converted into 0 to 1 scale value, z = the value of key indicator, s =the lowest possible value of key indicator (i.e. s = 0), t = the highest value for that key indicator
3) Calculation of irrigation sustainability index (ISI) (Eq.3.5) for all zones.
4) Classification of irrigation sustainability index into five classes i.e. very high, high, moderate, low, and very low using class interval (equal) approach. The higher index scores mean better irrigation sustainability area.

### 3.5.5 Generating irrigation sustainability index map

The GIS technique was used to create irrigation sustainability map to visualize the locations of the areas that have certain level of irrigation sustainability.

## Chapter 4
## Results and Discussions

### 4.1 Key Factors Affecting Irrigation System

Principal component analysis (PCA) is used to find out the dominant factor affecting irrigation system. Principal components (PCs) are modeled into a linear function of all the observed variables which the first component account for the highest possible share of the observed variance and the one with the next highest variance is the second component. Therefore, only the principal component which have a high factor loading (eigenvalue $\geq 1$) were examined. Component loadings are used to measure correlation between variables and the components. Loading close to $\pm 1$ indicates that a strong correlation between a variable and the component while loading close to zero indicates a weak correlation. According to Singh et al. (2007), those variables exhibiting a rotated absolute loading value greater than 0.75 are strongly loaded on a component.

In this principal component, only highly weighted variables are retained from each principal component. When more than one variable is retained within a principal component, their linear correlations are calculated to determine whether the variable can be considered redundant and, therefore, eliminate from the components. If they are correlated, then each variable is considered as important factor and is retained in the component. The identified variables are defined as factors affecting irrigation.

#### 4.1.1 Factors affecting irrigation system at KPP in wet season

There are 26 variables used in the analysis as shown in Table 4.1. These variables are 5, 8, 2 and 11 variables of physical, socio economic, environmental and institutional groups. Using factor data reduction in the SPSS software and considering the criteria of (Bartlett's test of sphericity ($p<0.05$) and sampling adequacy value (KMO) $\geq 0.5$) from the result.

Only one variable which has high factor loading within the PC is selected as the representative of the group. The result of PCA for KPP in wet season and their factors loading corresponding to the PCs are shown in Table 4.2.

The components are rotated with varimax method and PCA result indicated that there are five principal components (PCs) with the acceptable value (eigenvalue $\geq 1.3$, KMO=0.703 and $p<0.0001$) and with an overall cumulative variance of about 73.87 %. The sequences of the selected PCs and their weights of KPP in wet season are shown in Table 4.3.

Table 4.1 The Variables Used for PCA in KPP in Wet Season

| Variables | Initial | Extraction |
|---|---|---|
| Topography (elevation) | 1 | 0.75 |
| Flow ratio_wet | 1 | 0.64 |
| Field application ratio_wet | 1 | 0.71 |
| Ditch condition (clean/smooth) | 1 | 0.86 |
| Drainage ditch condition (clean/smooth) | 1 | 0.85 |
| Household member | 1 | 0.52 |
| Age structure | 1 | 0.85 |
| Experience of farmer (year) | 1 | 0.84 |
| Land tenure | 1 | 0.67 |
| Production cost_wet | 1 | 0.97 |
| Farm income_wet | 1 | 0.93 |
| B/C_wet | 1 | 0.68 |
| Water user conflict occurrence | 1 | 0.55 |
| Soil property_(pH) | 1 | 0.64 |
| Irrigation water quality_(pH)_wet | 1 | 0.73 |
| Number of staff | 1 | 0.73 |
| Work load of staff | 1 | 0.70 |
| Satisfaction on cultivated areas survey by WUG before irrigation season | 1 | 0.67 |
| Satisfaction on planning of water delivery schedule by RID staffs and WUG | 1 | 0.76 |
| Satisfaction on meeting between Chief of WUG and WUG for schedule planning agreement | 1 | 0.66 |
| Satisfaction on listen to the opinion of WUG listening by RID staffs | 1 | 0.60 |
| Satisfaction on announcement of the irrigation schedule to all WUG | 1 | 0.45 |
| Satisfaction on accountability of timeliness and fairness of water distribution | 1 | 0.61 |
| Satisfaction on adequacy of water distribution | 1 | 0.57 |
| Matching of farm operations with RID water delivery | 1 | 0.54 |
| Reliability of continuous flow | 1 | 0.70 |

Table 4.2 Result of PCA for KPP in Wet Season

| Variables | Components | | | | | Communalities |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | |
| Topography (elevation) | -0.488 | | 0.691 | | | 0.73 |
| Ditch condition (clean/smooth) | | 0.153 | | 0.918 | | 0.87 |
| Drainage ditch condition (clean/smooth) | | | | 0.921 | | 0.86 |
| Age structure | | | | | 0.913 | 0.84 |
| Experience of farmer (year) | | | | | 0.916 | 0.85 |
| Number of staff | | | 0.805 | | | 0.66 |
| Work load of staff | | -0.134 | 0.819 | | | 0.70 |
| Satisfaction on cultivated areas survey by WUG before irrigation season | 0.879 | | | | | 0.78 |
| Satisfaction on planning of water delivery schedule by RID staffs and WUG | 0.887 | 0.160 | | | | 0.82 |
| Satisfaction on meeting between Chief of WUG and WUG for schedule planning agreement | 0.822 | 0.202 | -0.184 | | | 0.75 |
| Satisfaction on RID staffs listen to the opinion of WUG listening by RID staffs | 0.457 | 0.633 | | 0.123 | | 0.63 |
| Satisfaction on accountability of timeliness and fairness of water distribution | | 0.685 | -0.121 | 0.211 | | 0.54 |
| Matching of farm operations with RID water delivery | 0.177 | 0.734 | | | | 0.58 |
| Reliability of continuous flow | | 0.853 | | | | 0.74 |

Note: Loading values less than 0.10 are ignored
Factor loadings which are underlined are considered highly weighted (key factor)

Table 4.3 Principal Components (PCs) for KPP in Wet Season

| PCs | Eigenvalue | Variance (% ) | Cumulative of Variance (%) | Weight* | MDS- Variables |
|---|---|---|---|---|---|
| 1 | 2.738 | 19.559 | 19.559 | 0.265 | Satisfaction on planning of water delivery schedule by RID staffs and WUG |
| 2 | 2.265 | 16.176 | 35.736 | 0.219 | Reliability of continuous flow |
| 3 | 1.858 | 13.269 | 49.005 | 0.180 | Workload of staff |
| 4 | 1.786 | 12.756 | 61.761 | 0.173 | Drainage ditch condition (clean/smooth) |
| 5 | 1.696 | 12.111 | 73.872 | 0.164 | Experience of farmer (year) |

Note : Weight* = % of variance of PCs / % of total variance

All of these key factors have positive effect on the irrigation system. There are one, one and three variables from physical factor (drainage ditch condition), socio economic factor (experience of farmer) and institutional factor (satisfaction on planning water delivery schedule between RID staffs and WUG, reliability of continuous flow and workload of staff), respectively. The strength, effect and interrelationship of each factor are discussed in the following paragraph.

The first factor which influences the irrigation system is the degree of satisfaction on planning of water delivery schedule by RID staff and WUG. It has a highest variance 19.56 % of total variance compared to the other factors as presented in Table 4.3. This factor explains that Kamphaengsaen project has the pre-season crop planning process. The amount of water use is estimated by the RID staff using area of crop and type of crop which is surveyed by the water user group. Water availability, actual crop area and rainfall are considered in planning and weekly scheduling of irrigation. Hence, schedule planning of the water delivery positively affects the irrigation system and indicated an important factor.

The second factor which influences the irrigation system is the reliability of continuous flow during the irrigation period. This factor has 16.18 % of total variance. Here term reliability means adequacy of water diverted to the crop at an appropriate time. Furthermore, it should be possible for each farmer to know in advance when and how much water can be diverted to their plots without time constraint and the amount diverted. However, there is no rule and regulation to punish the farmer who breaks these agreements. The upstream farmers take the advantage of the upstream location by ignoring gate operation and farming plan. The degree of satisfaction on reliability of continuous flow during the irrigation season is considered to have positive influence on irrigation system management.

The third factor is the work load of RID staff. It has 13.27 % total variance from the five key factors. It defines the ability of manpower that is responsible for operation and maintenance of irrigated area in 27 zones. The RID staff in this study are operation and maintenance staffs for example; zoneman in each zone with an approximated area of 1,498 hectares, gate tender and canal tender for each zone. The zoneman is responsible for water control and for liaison with irrigators. However, the numbers of staffs are not uniform throughout the 27 zones. The work load of RID staff hence affects the operation and maintenance of irrigation system in each zone. According to Loof et al. (1999), the number of staff are not uniform throughout the sub-system. This has an important impact on the problems of decision making in regard to water management, because the staff ratios are not adequate for the proper accomplishment of management information tasks such as record-keeping and conversion of water levels to discharges.

The satisfaction on drainage ditch condition (clean/smooth) is the fourth factor that influences the irrigation system in KPP which is entirely based on open channel drainage by gravity. It shows 12.76 % of total variance. The drainage system is under maintenance of KPP. Due to the flat topography, some zones in KPP water was pump out of the field to the drainage system during wet season. Moreover, some areas have no drainage way because of newly constructed soil blocking the old drainage way as in zone 7 and 8.

The fifth factor is experience of farmers. It explains 12.11 % of total variance among the variance of five key factors. The farmers in KPP have experiences less than 15 years, 16-

25 years, 26-35 years, 36-45 years and greater than 45 years contributed to 24.5 %, 31.8 %, 25.3 %, 12.5 % and 5.9 % respectively. However, this factor shows that farmers having high experience know when to harvest and fertilize, how much to fertilize and how to take care of the crops planted compared to the farmers having low experience who plant their crops by trial and error methods. For example, high experience farmers know the harvesting time of rice by touching the ear of the paddy and their experiences bring good price due to the appropriate harvesting time.

### 4.1.2 Factors affecting irrigation system at KPP in dry season

There are 26 variables using in the analysis as shown in Table 4.4. These variables are 5, 8, 2 and 11 variables of physical, socio economic, environmental and institutional groups.

Table 4.4 The Variables Used for PCA in KPP in Dry Season

| Variables | Initial | Extraction |
|---|---|---|
| Topography (elevation) | 1 | 0.73 |
| Flow ratio_dry | 1 | 0.72 |
| Field application ratio_dry | 1 | 0.79 |
| Ditch condition (clean/smooth) | 1 | 0.85 |
| Drainage ditch condition (clean/smooth) | 1 | 0.86 |
| Household member | 1 | 0.51 |
| Age structure | 1 | 0.81 |
| Experience of farmer (year) | 1 | 0.83 |
| Land tenure | 1 | 0.55 |
| Production cost_dry | 1 | 0.97 |
| Farm income_dry | 1 | 0.94 |
| B/C_dry | 1 | 0.65 |
| Water user conflict occurrence | 1 | 0.57 |
| Soil property_(pH) | 1 | 0.77 |
| Irrigation water quality_(pH)_dry | 1 | 0.66 |
| Number of staff | 1 | 0.68 |
| Work load of staff | 1 | 0.74 |
| Satisfaction on cultivated areas survey by WUG before irrigation season | 1 | 0.71 |
| Satisfaction on planning of water delivery schedule by RID staffs and WUG | 1 | 0.77 |
| Satisfaction on meeting between Chief of WUG and WUG for schedule planning agreement | 1 | 0.65 |
| Satisfaction on listen to the opinion of WUG listening by RID staffs | 1 | 0.61 |
| Satisfaction on announcement of the irrigation schedule to all WUG | 1 | 0.55 |
| Satisfaction on accountability of timeliness and fairness of water distribution | 1 | 0.64 |
| Satisfaction on adequacy of water distribution | 1 | 0.67 |
| Matching of farm operations with RID water delivery | 1 | 0.51 |
| Reliability of continuous flow | 1 | 0.77 |

Only one variable which has high factor loading within the PC is selected as the representative of the group. The result of PCA for KPP in dry season and their factor loading corresponding to the PCs are shown in Table 4.5.

Table 4.5 Result of PCA for KPP in Dry Season

| Variables | Components | | | | | Communalities |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | |
| Topography (elevation) | -0.488 | | 0.691 | | | 0.73 |
| Ditch condition (clean/smooth) | | 0.153 | | 0.918 | | 0.87 |
| Drainage ditch condition (clean/smooth) | | | | 0.921 | | 0.86 |
| Age structure | | | | | 0.913 | 0.84 |
| Experience of farmer (year) | | | | | 0.916 | 0.85 |
| Numer of RID staff | | | 0.805 | | | 0.66 |
| Work load of staff | | -0.134 | 0.819 | | | 0.70 |
| Satisfaction on cultivated areas survey by WUG before irrigation season | 0.879 | | | | | 0.78 |
| Satisfaction on planning of water delivery schedule by RID staffs and WUG | 0.887 | 0.160 | | | | 0.82 |
| Satisfaction on meeting between Chief of WUG and WUG for schedule planning agreement | 0.822 | 0.202 | -0.184 | | | 0.75 |
| Satisfaction on listen to the opinion of WUG listening by RID staffs | 0.457 | 0.633 | | 0.123 | | 0.63 |
| Satisfaction on accountability of timeliness and fairness of water distribution | | 0.685 | -0.121 | 0.211 | | 0.54 |
| Matching of farm operations with RID water delivery | 0.177 | 0.734 | | | | 0.58 |
| Reliability of continuous flow | | 0.853 | | | | 0.74 |

Note: Loading values less than 0.10 are ignored

: Factor loadings which are underlined are considered highly weighted (key factor)

The components are rotated with varimax method and PCA result indicates that there are five principal components (PCs) with the acceptable value (eigenvalue ≥1.3, KMO=0.703 and $p<0.0001$) and with an overall cumulative variance of about 73.87 %. The sequences of the selected PCs and their weights of KPP in wet season are shown in Table 4.6.

Table 4.6 Principal Components (PCs) for KPP in Dry Season

| PCs | Eigenvalue | Variance (% ) | Cumulative of Variance (%) | Weight* | MDS- Variables |
|---|---|---|---|---|---|
| 1 | 2.738 | 19.559 | 19.559 | 0.265 | Satisfaction on planning of water delivery schedule by RID staffs and WUG |
| 2 | 2.265 | 16.176 | 35.736 | 0.219 | Reliability of continuous flow |
| 3 | 1.858 | 13.269 | 49.005 | 0.180 | Workload of staff |
| 4 | 1.786 | 12.756 | 61.761 | 0.173 | Ditch condition (clean/smooth) |
| 5 | 1.696 | 12.111 | 73.872 | 0.164 | Experience of farmer (year) |

Note : Weight* = % of variance of PCs / % of total variance

The result indicated that the factors are not different in wet and dry season. In dry season, the fourth factor explains degree of satisfaction on ditch condition (clean/smooth) instead of drainage ditch condition that influences irrigation system in KPP, the others factors are similar with wet season. It explains 12.76 % of total variance. Kamphaengsaen project is responsible for the maintenance of the primary and secondary levels. Farmers are expected to take over the tertiary level. Ditch is essential to preserve access flow to their plots. Therefore, water user leader makes an appointment to maintain or repair ditch before starting of irrigation season in dry season. Cleaning and grass cutting are takes to be undertaken annually, while dredging is done according to necessary.

There are one, one and three variables from physical, socio economic and institutional factor, respectively as shown in table 4.6. These five factors are the key factors with positive effect on irrigation system. This can be used for the different zone boundaries.

### 4.1.3 Factors affecting irrigation system at PPP in wet season

There are 26 variables using in the analysis as shown in Table 4.7. These variables are 5, 8, 2 and 11 of physical, socio economic, environmental and institutional groups. Using factor data reduction in the SPSS software and considering the criteria of Bartlett's test of sphericity ($p<0.05$) and sampling adequacy value ($KMO \geq 0.5$) from the result.

Table 4.7 The Variables Used for PCA in PPP in Wet Season

| Variables | Initial | Extraction |
|---|---|---|
| Topography (elevation) | 1 | 0.70 |
| Flow ratio_wet | 1 | 0.83 |
| Field application ratio_wet | 1 | 0.95 |
| Ditch condition (clean/smooth) | 1 | 0.72 |
| Drainage ditch condition (clean/smooth) | 1 | 0.82 |
| Household member | 1 | 0.42 |
| Age structure | 1 | 0.79 |
| Experience of farmer (year) | 1 | 0.76 |
| Land tenure | 1 | 0.56 |
| Production cost_wet | 1 | 0.89 |
| Farm income_wet | 1 | 0.87 |
| B/C_wet | 1 | 0.90 |
| Water user conflict occurrence | 1 | 0.57 |
| Soil property_(pH) | 1 | 0.79 |
| Irrigation water quality_(pH)_wet | 1 | 0.64 |
| Number of staff | 1 | 0.97 |
| Work load of staff | 1 | 0.92 |
| Satisfaction on cultivated areas survey by WUG before irrigation season | 1 | 0.76 |
| Satisfaction on planning of water delivery schedule by RID staffs and WUG | 1 | 0.79 |
| Satisfaction on meeting between Chief of WUG and WUG for schedule planning agreement | 1 | 0.67 |
| Satisfaction on listen to the opinion of WUG listening by RID staffs | 1 | 0.66 |
| Satisfaction on announcement of the irrigation schedule to all WUG | 1 | 0.48 |
| Satisfaction on accountability of timeliness and fairness of water distribution | 1 | 0.67 |
| Satisfaction on adequacy of water distribution | 1 | 0.62 |
| Matching of farm operations with RID water delivery | 1 | 0.56 |
| Reliability of continuous flow | 1 | 0.64 |

Only one variable which has high factor loading within the PC is selected as the representative of the group. The variable considered in the PCA and their factor loading corresponding to the PCs are shown in Table 4.8. However, since coefficient correlations between the highly weighted variables are significant, only the factor with highest correlation with the PCs was selected as representative of the group, and this is consistent with Andrew et al. (2002) which used PCA for soil quality assessment and Halim et al. (2006) used PCA for soil erosion hazard assessment, moreover; Singh et al. (2007) also used PCA to evaluate water quality. The PCA result of PPP in wet season and their factor loading corresponding to the PCs are shown in Table 4.8.

Table 4.8 Result of PCA for PPP in Wet Season

| Variables | Components | | | | | Communalities |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | |
| Flow ratio_wet | 0.761 | -0.168 | -0.129 | | | 0.63 |
| Field application ratio_wet | <u>0.913</u> | -0.241 | | | | 0.89 |
| Ditch condition (clean/smooth) | | | | <u>0.896</u> | | 0.81 |
| Drainage ditch condition (clean/smooth) | | | | <u>0.902</u> | | 0.83 |
| Age structure | -0.100 | | | | <u>0.893</u> | 0.81 |
| Experience of farmer (year) | 0.125 | | | | <u>0.900</u> | 0.83 |
| Production cost_wet | | 0.404 | | | | 0.17 |
| Soil property_(pH) | -0.835 | | | | | 0.71 |
| Number of staff | <u>0.968</u> | | 0.132 | | | 0.96 |
| Work load of staff | <u>0.866</u> | 0.129 | 0.290 | | | 0.86 |
| Satisfaction on cultivated areas survey by WUG before irrigation season | | <u>0.900</u> | 0.103 | | | 0.83 |
| Satisfaction on planning of water delivery schedule by RID staffs and WUG | | <u>0.854</u> | 0.197 | | 0.101 | 0.78 |
| Satisfaction on meeting between Chief of WUG and WUG for schedule planning agreement | | 0.801 | | | | 0.65 |
| Satisfaction on listen to the opinion of WUG listening by RID staffs | | 0.449 | 0.629 | | | 0.60 |
| Satisfaction on accountability of timeliness and fairness of water distribution | | -0.117 | <u>0.812</u> | -0.128 | | 0.70 |
| Matching of farm operations with RID water delivery | 0.142 | 0.204 | 0.680 | 0.239 | | 0.58 |
| Reliability of continuous flow | | | 0.691 | -0.360 | | 0.62 |

Note: Loading values less than 0.10 are ignored
Factor loadings which are underlined are considered highly weighted (key factor)

The components are rotated with varimax method and PCA result indicated that there are five principal components (PCs) with the acceptable value (eigenvalue≥1.2, KMO=0.661 and $p<0.0001$) and with an overall cumulative variance of about 72.14 %. The sequences of the selected PCs and their weights of PPP in wet season are shown in Table 4.9.

Table 4.9 Principal Components (PCs) for PPP in Wet Season

| PCs | Eigenvalue | Variance (% ) | Cumulative of Variance (%) | Weight* | MDS- Variables |
|---|---|---|---|---|---|
| 1 | 4.034 | 23.729 | 23.729 | 0.329 | Number of staff |
| 2 | 3.166 | 18.623 | 42.352 | 0.258 | Satisfaction on cultivated areas survey by WUG before irrigation season |
| 3 | 2.074 | 12.200 | 54.551 | 0.169 | Satisfaction on accountability of timeliness and fairness of water distribution |
| 4 | 1.587 | 9.335 | 63.887 | 0.129 | Drainage ditch condition (clean/smooth) |
| 5 | 1.403 | 8.256 | 72.142 | 0.114 | Experience of farmer (year) |

Note : Weight* = % of variance of PCs / % of total variance

The contribution of key factors affecting irrigation system show physical factor (drainage ditch condition), socio-economic factor (experience of farmer and production cost) and institutional factor (satisfaction on survey cultivated areas of WUG before irrigation season and satisfaction on accountability on timeliness and fairness of water distribution) respectively. These five factors are component key factors which have positive effect on irrigation system except production cost. The strength effect and interrelationship of each factor are discussed in following paragraph.

The first factor is number of staff. It explains 23.73 % of total variance from the five key factors. It defines the ability of manpower that is responsible for operation and maintenance of irrigated area in 11 zones. The RID staff in this study means operation and maintenance staffs for example; zoneman in each zone with an approximated area of 1,568 hectares, gate tender and canal tender for each zone. The zoneman is responsible for water control and for liaison with irrigators. However, the numbers of staff are not uniform throughout the 11 zones. The number of staff hence effects the operation and maintenance of irrigation system in each zone. According to Loof et al. (1999), the numbers of staff are not uniform throughout the sub-system. This has an important impact on the problems of decision making in regard to water management, because the staff ratios are not adequate for the proper accomplishment of management information tasks such as record-keeping and conversion of water levels to discharges.

The second factor which influences irrigation system is the satisfaction on WUA leader who surveyed the crop area before the irrigation season. The indicator shows a variance 18.62 % with a positive loading. This factor can be explained that in PPP which has the pre seasonal crop planning process. The Chief of WUA surveys the crop area before irrigation season to estimate the amount of water used to prepare the pre-seasonal plan. If chief of WUA surveyed the crop area before the irrigation season, he can be estimated the amount of water requirement suitable for the crop. Hence, this factor truly affects the irrigation system.

The third factor is satisfaction on accountability of timeliness and fairness in distribution system. It has 12.20 % of total variance with the positive loading. It deals with timeliness in term of water delivery to the farm and fairness in term of water distribution within the system. This factor however identifies transparency, fairness and timeliness of the zoneman who is responsible for the irrigation service of each zone and positive affects the irrigation system.

The degree of satisfaction on drainage ditch condition (clean/smooth) is the fourth factor that influences irrigation system in Phophraya. It explains 9.33% of total variance. The drainage system is very important in wet season because PPP is the plain and low plain area which has also drainage system for flooding protection. Moreover, some zone in PPP such as zone 10 and zone 11 used drainage water for irrigated crop.

The fifth factor is experience of farmer. It explains 8.26% of total variance. In the Phophraya project found that the experience less than 15 years (28.95%), between 15-25 years (32.23 %), between 26-35 years (27.66%) , between 36-45 years (13.17%) and more than 45 years (5.52%). This factor shows that farmers having high experience know when to harvest and fertilize, how much fertilize intake and how to take care his crop planted. Farmers having low experience plant his crop with trial and error. For example the high experience farmer knows the harvesting time of rice with touching the ear of paddy. This experience brings good price because of appropriate relative humidity.

### 4.1.4 Factors affecting irrigation system at PPP in dry season

There are 26 variables using in the analysis as shown in Table 4.10. These variables are 5, 8, 2 and 11 variables of physical, socio economic, environmental and institutional groups.

Table 4.10 The Variables Used for PCA in PPP in Dry Season

| Variables | Initial | Extraction |
|---|---|---|
| Topography (elevation) | 1 | 0.70 |
| Flow ratio_dry | 1 | 0.75 |
| Field application ratio_dry | 1 | 0.90 |
| Ditch condition (clean/smooth) | 1 | 0.76 |
| Drainage ditch condition (clean/smooth) | 1 | 0.83 |
| Household member | 1 | 0.49 |
| Age structure | 1 | 0.77 |
| Experience of farmer (year) | 1 | 0.76 |
| Land tenure | 1 | 0.59 |
| Production cost_dry | 1 | 0.92 |
| Farm income_dry | 1 | 0.81 |
| B/C_dry | 1 | 0.87 |
| Water user conflict occurrence | 1 | 0.70 |
| Soil property_(pH) | 1 | 0.84 |
| Number of staff | 1 | 0.96 |
| Work load of staff | 1 | 0.91 |
| Satisfaction on cultivated areas survey by WUG before irrigation season | 1 | 0.80 |
| Satisfaction on planning of water delivery schedule by RID staffs and WUG | 1 | 0.78 |
| Satisfaction on meeting between Chief of WUG and WUG for schedule planning agreement | 1 | 0.64 |
| Satisfaction on listen to the opinion of WUG listening by RID staffs | 1 | 0.61 |
| announcement of the irrigation schedule to all WUG | 1 | 0.49 |
| Satisfaction on accountability of timeliness and fairness of water distribution | 1 | 0.65 |
| Satisfaction on adequacy of water distribution | 1 | 0.69 |
| Matching of farm operations with RID water delivery | 1 | 0.56 |
| Reliability of continuous flow | 1 | 0.64 |

Only one variable which has high factor loading within the PC is selected as the representative of the group. The PCA results of PPP in dry season and their factor loading corresponding to the PCs are shown in Table 4.11.

Table 4.11 Result of PCA for PPP in Dry Season

| Variables | Components | | | | | | Communalities |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | |
| Topography (elevation) | 0.539 | 0.424 | -0.387 | | -0.112 | | 0.64 |
| Flow ratio_dry | 0.652 | | 0.160 | 0.132 | 0.184 | -0.288 | 0.58 |
| Field application ratio_dry | <u>0.873</u> | -0.317 | | | | | 0.87 |
| Ditch condition (clean/smooth) | | | | <u>0.839</u> | | 0.136 | 0.73 |
| Drainage ditch condition (clean/smooth) | | | | 0.835 | | | 0.72 |
| Age structure | -0.113 | | | 0.251 | 0.210 | <u>0.691</u> | 0.60 |
| Experience of farmer (year) | 0.143 | | | 0.167 | 0.138 | <u>0.688</u> | 0.55 |
| Land tenure | | | -0.423 | | 0.537 | 0.241 | 0.54 |
| Production cost_dry | | 0.149 | -0.160 | | <u>-0.912</u> | 0.221 | 0.93 |
| Farm income_dry | -0.151 | 0.162 | -0.152 | -0.244 | -0.277 | 0.660 | 0.64 |
| B/C_dry | | | | -0.174 | 0.735 | 0.340 | 0.69 |
| Water user conflict occurrence | 0.161 | 0.174 | <u>-0.697</u> | -0.217 | | | 0.60 |
| Soil property_(pH) | -0.893 | | 0.158 | | | | 0.83 |
| Number of staff | <u>0.980</u> | | | | | | 0.96 |
| Work load of staff | <u>0.943</u> | | 0.117 | | | | 0.91 |
| Satisfaction on cultivated areas survey by WUG before irrigation season | | <u>0.925</u> | | | | | 0.86 |
| Satisfaction on planning of water delivery schedule by RID staffs and WUG | | <u>0.893</u> | | | | | 0.81 |
| Satisfaction on meeting between Chief of WUG and WUG for schedule planning agreement | | 0.806 | | | | | 0.68 |
| Satisfaction on accountability of timeliness and fairness of water distribution | 0.122 | | <u>0.764</u> | -0.207 | | 0.137 | 0.66 |
| Reliability of continuous flow | 0.160 | 0.155 | 0.613 | -0.435 | | | 0.62 |

Note: Loading values less than 0.10 are ignored

: Factor loadings which are underlined are considered highly weighted (key factor)

The components are rotated with varimax method and PCA results indicated that there are six principal components (PCs) with the acceptable value (eigenvalue≥1.3, KMO=0.565 and p<0.0001) and with an overall cumulative variance of about 72.18 %. The sequences of the selected PCs and their weights of PPP in dry season are shown in Table 4.12.

Table 4.12 Principal Components (PCs) for PPP in Dry Season

| PCs | Eigenvalue | Variance (% ) | Cumulative of Variance (%) | Weight* | MDS- Variables |
|---|---|---|---|---|---|
| 1 | 4.281 | 21.403 | 21.403 | 0.297 | Number of staff |
| 2 | 2.715 | 13.576 | 34.979 | 0.188 | Satisfaction on cultivated areas survey by WUG before irrigation season |
| 3 | 1.910 | 9.551 | 44.531 | 0.132 | Satisfaction on accountability of timeliness and fairness of water distribution |
| 4 | 1.897 | 9.487 | 54.018 | 0.131 | Ditch condition (clean/smooth) |
| 5 | 1.868 | 9.342 | 63.360 | 0.129 | Production cost |
| 6 | 1.764 | 8.818 | 72.178 | 0.122 | Experience of farmer (year) |

Note : Weight* = % of variance of PCs / % of total variance

The result indicated that the factors are not different in wet and dry season. In dry season, the first component is number of RID staff considered in this study. Degree of satisfaction on ditch condition, the fourth factor, influences irrigation system in PPP instead of drainage ditch condition. The sixth component has two factors with high loading factor i.e. age structure (0.691) and experience of farmer (0.688). Although age structure has higher factor loading than experience of farmer, experience of farmer is likely to play more supporting role in term of socio factor, thus experience of farmer is considered in this study. Whereas the other factors are similar to wet season factor except production cost in the fifth component (PC5). Production cost shows a variance 9.34 % of total variance with negative loading. It is found to be the key factor that affects irrigation system in PPP. Production cost involved a) farm input cost such as seed, fertilizer, pesticide and herbicide, other materials, pumping, land renting b) labor cost such as land preparation, seeding, planting and harvesting c) transportation. In this project, only land renting and labor costs affect the production cost. It is due to the fact that the cost of land preparation, broadcasting, fertilization, harvesting and transportation are common between land renting. In some cases mutual help among the farmers can reduce the labour cost for land preparation and harvesting.

Phophraya project is responsible for the maintenance of the primary and secondary levels. The canal system is mostly earth canal (90 %). The main problem is weed. Farmers are expected to take over at the tertiary level. Water user leader makes an appointment to maintain or repair the ditch before irrigation is started in the dry season. Ditch maintenance is essential to preserve access flow to their plots. Cleaning and grass cutting are tasks undertaken annually, while dredging is done as necessary.

The key factors are different between the two projects. The common factors to both systems are manpower (workload, number of staff), ditch condition, drainage condition and experience of farmer (year). The specific factors for KPP are satisfaction on planning of water delivery schedule by RID staffs and WUG and reliability of continuous flow. Satisfaction on cultivated areas survey by WUG before irrigation season, satisfaction on accountability of timeliness and fairness of water distribution and production cost on the other hand, are the specific factors for PPP.This can be explained by the fact that KPP shows a diversity of crops such as rice, sugarcane, vegetable and fruit, while rice is the main crop in PPP. Water distribution in KPP is complex and difficult to manage therefore satisfaction on planning of water delivery schedule by RID staffs and WUG and reliability of continuous flow are shown. In PPP on the other hand, Farmer's land ownership, application of fertilizer and chemical are factors contributing to production cost in term of land renting, fertilizer, herbicide and pesticide. Farmers pay high price for land renting because they have own farm land less than 40% of total areas and they apply more fertilizer for rice cultivation.

## 4.2 Irrigation Sustainability Index (ISI)

### 4.2.1 Irrigation sustainability of KPP

Principal component analysis (PCA) is used to find out the key indicators from 16 indicators in total which are divided into two, five, four and five indicators of physical, socio-economic, environmental and institutional indicators respectively. Table 4.13 shows indicators which used to analyze PCA.

Table 4.13 The Indicators Used for PCA in KPP

| Indicators | Initial | Extraction |
|---|---|---|
| Flow ratio | 1 | 0.77 |
| Field application ratio | 1 | 0.83 |
| Crop yield | 1 | 0.36 |
| Farm income | 1 | 0.90 |
| Net farm income | 1 | 0.91 |
| Awareness on irrigation water use | 1 | 0.65 |
| Water user conflict occurrence | 1 | 0.36 |
| Soil property_(pH) | 1 | 0.60 |
| Irrigation water quality_(pH) | 1 | 0.73 |
| Perception of drained water quality | 1 | 0.72 |
| Perception of soil quality | 1 | 0.58 |
| Satisfaction on adequacy of water distribution | 1 | 0.75 |
| Matching of farm operations with RID water delivery | 1 | 0.67 |
| Reliability of continuous flow | 1 | 0.72 |
| Satisfaction on water delivery planning process | 1 | 0.47 |
| Willingness to pay | 1 | 0.64 |

Table 4.14 shows the variables that are considered in PCA as well as their factor loadings. Only the variable that has a higher factor loading in the PC is selected as the representative of the group. For example, if farm income and net farm income in PC1 show almost the same value, say 0.984 and 0.985 respectively then the net farm income is selected as the representative of the group and becomes the dominant indicator.

Table 4.14 Result of PCA for KPP

| Indicators | Components | | | | Communalities |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | |
| Flow ratio | | 0.258 | -0.219 | <u>0.823</u> | 0.79 |
| Field application ratio | | -0.173 | | <u>0.888</u> | 0.83 |
| Farm income | <u>0.984</u> | | | | 0.97 |
| Net farm income | <u>0.985</u> | | | | 0.97 |
| Awareness on irrigation water use | | <u>0.793</u> | -0.111 | | 0.65 |
| Perception of drained water quality | | <u>0.719</u> | | -0.112 | 0.53 |
| Perception of soil quality | | <u>0.735</u> | 0.164 | 0.108 | 0.58 |
| Satisfaction on adequacy of water distribution | -0.145 | 0.182 | 0.627 | | 0.45 |
| Matching of farm operations with RID water delivery | | | <u>0.837</u> | 0.122 | 0.73 |
| Reliability of continuous flow | | | <u>0.793</u> | -0.190 | 0.67 |

Note: Loading values less than 0.10 are ignored
: Factor loadings which underlined are considered highly weighted (key factor)

The components are rotated with varimax method, and the PCA results show four principal components (PCs) with acceptable values (eigenvalue $\geq$ 1.2, KMO=0.582 and $p<0.0001$). Table 4.15 shows the sequences of the selected principal components (PCs) in KPP together with their corresponding weights. The selected PCs or indicators are used to develop the irrigation sustainability index (ISI) equation for KPP study area.

Table 4.15 Principal Components (PCs) for KPP

| PCs | Eigenvalue | Variance (% ) | Cumulative of Variance (%) | Weight* | MS- Indicators | Symbol |
|---|---|---|---|---|---|---|
| 1 | 1.990 | 19.898 | 19.898 | 0.277 | Net farm income | $X_1$ |
| 2 | 1.824 | 18.239 | 38.137 | 0.254 | Awareness on irrigation water use | $X_2$ |
| 3 | 1.817 | 18.165 | 56.302 | 0.253 | Matching of farm operations with RID water delivery | $X_3$ |
| 4 | 1.551 | 15.512 | 71.814 | 0.216 | Field application ratio | $X_4$ |

Note : Weight* = % of variance of PCs / % of total variance

ISI equation is developed based on Equation (3.5) using all indicators remaining within the components with eigenvalue $\geq$ 1.2. Finally, the ISI equation is shown as follows.

$$ISI = 0.277Y_{(X1)} + 0.254Y_{(X2)} + 0.253Y_{(X3)} + 0.216Y_{(X4)} \quad (4.1)$$

Where:
Y = Score of indicator
$X_1$ = Net farm income
$X_2$ = Awareness on irrigation water use
$X_3$ = Matching of farm operations with RID water delivery
$X_4$ = Field application ratio

This formula is used to determine the ISI of each zone as shown in Table 4.16. The key indicators that show high impact on irrigation sustainability in the study area are one physical, two socio-economic and one institutional indicator. The relationship of the individual indicator is discussed in the following paragraph.

The first component has the highest variance 19.90 % of among the other four components with net farm income as the indicator for positive loading. Farm income and net farm income represent the socio-economic indicators in the group. In this study, the net farm income was considered as key index of the first component. According to MAF (1997) and Stockle et al. (1994), Smith and McDonald (1998) cited in Zhen and Routray (2003), the net income is an indicator to assess the sustainability of agriculture. The income (e.g. selling price of a product) and the production cost reveals the net farm income and influences the sustainability of irrigation system. Net farm income implies income from crop production and it is a value obtained by subtracting the income by the production cost. Production cost is an input cost and involves the cost of a) farm input cost such as seed fertilizer, pesticide and herbicide, other materials, pumping, land renting b) labor cost such as land preparation, seeding and planting, harvesting cost c) transportation d) fee and tax. The income is selling price of a product, therefore; crop yield and selling price are an influence for the income. The selling price of sugarcane is not different because the factory set up the constant price for the products. However, the selling price of rice depends on trader and moisture content of rice and selling price of asparagus depends on quality of asparagus.

The indicator of second component that influences the sustainability of irrigation system is awareness on use of irrigation water. It has 18.24 % of total variance and explains the farmer how to use water wisely, ways to reduce waste and increase water use efficiency. Poor irrigation practice and lack of farmer awareness have resulted in excessive water usage. Lack of awareness led to inefficient water use. These are the major challenges that might save irrigation water in the future (Ahmed et al., 2007). This however reveals the awareness on use of irrigation water has positive influence on the sustainability of the irrigation system hence higher the awareness on irrigation water use, higher the sustainability of the irrigation system.

The matching of farm operations with RID water delivery is an institution indicator in third component and has 18.17% of total variance with a positive loading. According to Kellett et al. (2005), the match between water delivery schedule and agricultural operation was considered as an indicator of this component. The distribution on farm schedule is prepared on a weekly basis (7 days) specifying timing for individual farms. Irrigation scheduling helps to conserve water and decision making on the timing and quantity of water supply to commensurate with crop needs. It is one of the key activities that has the potential to improve performance of the system especially its productivity, equity and stability (Pundarikanthan and Santhi, 1996). The KPP has varieties of crops; therefore water distribution in KPP is complex and difficult to manage. Moreover, there are annual crop namely; asparagus, sugarcane and finger root planting in some zones such as zone 6 and 10 which need water through all year.

The fourth component is the field application ratio which is a physical indicator and has a variance of 15.51 % with positive loading. According to Cai et al. (2001), the ratio of the volume of water supplied to the total volume demanded is the volumetric reliability in term of physical indicator which used to quantify the amount of water used for crops are appropriate. The KPP has a weekly planning process, zoneman surveys the area and type of crops to estimate the required flow and summarizes the water requirement plan (on every Tuesday) and proposes to the chief of water allocation in order to distribute water to the control structure in the canal system.

To standardize the raw data of key indicators (Table E-7), Equation (3.7) is used to convert them into 0 to 1 scale as shown in Table E-8. Then Equation (4.1) is used to calculate ISI as shown in Table 4.16.

Table 4.16 Irrigation Sustainability Index (ISI) for KPP

| Zone | $X_1$ = Net farm income | $X_2$ = Awareness on irrigation water use | $X_3$ = Matching of farm operations with RID water delivery | $X_4$ = Field application ratio | ISI | ISI_class |
|---|---|---|---|---|---|---|
| 1 | 0.133 | 0.092 | 0.230 | 0.157 | 0.612 | 1 |
| 2 | 0.120 | 0.139 | 0.172 | 0.157 | 0.588 | 1 |
| 3 | 0.155 | 0.139 | 0.172 | 0.157 | 0.623 | 1 |
| 4 | 0.160 | 0.185 | 0.172 | 0.157 | 0.675 | 2 |
| 5 | 0.125 | 0.185 | 0.230 | 0.196 | 0.736 | 3 |
| 6 | 0.175 | 0.185 | 0.230 | 0.196 | 0.786 | 4 |
| 7 | 0.173 | 0.185 | 0.230 | 0.196 | 0.784 | 4 |
| 8 | 0.142 | 0.185 | 0.230 | 0.196 | 0.754 | 3 |
| 9 | 0.145 | 0.185 | 0.230 | 0.196 | 0.756 | 3 |
| 10 | 0.252 | 0.231 | 0.230 | 0.196 | 0.909 | 5 |
| 11 | 0.160 | 0.185 | 0.230 | 0.157 | 0.731 | 3 |
| 12 | 0.139 | 0.231 | 0.230 | 0.196 | 0.796 | 4 |
| 13 | 0.153 | 0.231 | 0.172 | 0.157 | 0.713 | 3 |
| 14 | 0.125 | 0.185 | 0.172 | 0.157 | 0.639 | 1 |
| 15 | 0.158 | 0.231 | 0.230 | 0.118 | 0.736 | 3 |
| 16 | 0.134 | 0.185 | 0.230 | 0.196 | 0.745 | 3 |
| 17 | 0.133 | 0.185 | 0.230 | 0.118 | 0.666 | 2 |
| 18 | 0.142 | 0.185 | 0.230 | 0.196 | 0.753 | 3 |
| 19 | 0.132 | 0.185 | 0.230 | 0.157 | 0.703 | 2 |
| 20 | 0.140 | 0.185 | 0.230 | 0.196 | 0.751 | 3 |
| 21 | 0.124 | 0.231 | 0.230 | 0.079 | 0.663 | 2 |
| 22 | 0.102 | 0.185 | 0.172 | 0.196 | 0.656 | 2 |
| 23 | 0.146 | 0.185 | 0.172 | 0.118 | 0.621 | 1 |
| 24 | 0.203 | 0.231 | 0.172 | 0.196 | 0.802 | 4 |
| 25 | 0.143 | 0.185 | 0.230 | 0.196 | 0.754 | 3 |
| 26 | 0.180 | 0.185 | 0.172 | 0.039 | 0.577 | 1 |
| 27 | 0.151 | 0.231 | 0.172 | 0.157 | 0.711 | 3 |

### 4.2.2 Irrigation sustainability of PPP

The irrigation sustainability indicators in PPP used 16 indicators which consist of two, five, four, five for physical, socio-economic, institutional and environment indicators respectively. Table 4.17 shows indicators used for principal component analysis for PPP.

Table 4.17 The Indicators Used for PCA for PPP

| Indicators | Initial | Extraction |
|---|---|---|
| Flow ratio | 1 | 0.85 |
| Field application ratio | 1 | 0.94 |
| Crop yield | 1 | 0.87 |
| Farm income | 1 | 0.90 |
| Net farm income | 1 | 0.82 |
| Awareness on irrigation water use | 1 | 0.79 |
| Water user conflict occurrence | 1 | 0.79 |
| Soil property_(pH) | 1 | 0.92 |
| Irrigation water quality_(pH) | 1 | 0.84 |
| Perception of drained water quality | 1 | 0.76 |
| Perception of soil quality | 1 | 0.86 |
| Satisfaction on adequacy of water distribution | 1 | 0.71 |
| Matching of farm operations with RID water delivery | 1 | 0.71 |
| Reliability of continuous flow | 1 | 0.74 |
| Satisfaction on water delivery planning process | 1 | 0.64 |
| Willingness to pay | 1 | 0.66 |

Table 4.18 shows the variables considered in the PCA and their factor loading corresponding to the PCs. PCA results indicated that there are four principal components (PCs) with the acceptable values (eigenvalue≥1.2, KMO=0.582 and p<0.0001)**.**

Table 4.18 Result of PCA for PPP

| Indicators | Components | | | | Communalities |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | |
| Flow ratio | | | -0.163 | <u>0.928</u> | 0.89 |
| Field application ratio | 0.148 | | | <u>0.918</u> | 0.87 |
| Crop yield | -0.119 | | <u>0.677</u> | 0.151 | 0.50 |
| Farm income | | | <u>0.862</u> | -0.273 | 0.82 |
| Net farm income | -0.110 | | <u>0.873</u> | -0.174 | 0.80 |
| Water user conflict occurrence | <u>-0.659</u> | | 0.196 | | 0.47 |
| Perception of drained water quality | <u>0.834</u> | | | | 0.71 |
| Perception of soil quality | <u>0.836</u> | | | | 0.71 |
| Satisfaction on adequacy of water distribution | -0.235 | <u>0.718</u> | | 0.362 | 0.70 |
| Matching of farm operations with RID water delivery | 0.453 | <u>0.667</u> | | | 0.66 |
| Reliability of continuous flow | | <u>0.687</u> | -0.148 | | 0.50 |
| Satisfaction on water delivery planning process | | <u>0.798</u> | | -0.161 | 0.66 |

Note: Loading values less than 0.10 are ignored
Factor loadings which are underlined are considered highly weighted (key factor)

Only one variable which has high factor loading within the PC is selected as the representative of the group. For example, there are perception of drained water quality and perception of soil quality having factor loading almost similar values (e.g. 0.834 and 0.836) in PC1. Although perception of soil quality has factor loading higher than perception of drained water quality, perception of drained water quality plays more supporting role in term of environmental indicator. This is due to some farmers using drainage water for irrigation in water scarce areas and they are aware of drained water quality. Moreover, soil fertility is good in this project. Thus, perception of drained water quality is considered as key indicator of this component. This also suggested consideration of indicator by Singh et al. (2007). Table 4.19 shows the sequences of the selected PCs and their weights. These indicators can be used to develop an equation of the irrigation sustainability index (ISI) for the different zones in PPP.

Table 4.19 Principal Components (PCs) for PPP

| PCs | Eigenvalue | Variance (% ) | Cumulative of Variance (%) | Weight* | MDS- Indicators | Symbol |
|---|---|---|---|---|---|---|
| 1 | 2.148 | 17.901 | 17.901 | 0.259 | Perception of drained water quality | $X_1$ |
| 2 | 2.089 | 17.412 | 35.312 | 0.252 | Satisfaction on adequacy of water distribution | $X_2$ |
| 3 | 2.064 | 17.200 | 52.513 | 0.248 | Net farm income | $X_3$ |
| 4 | 2.006 | 16.713 | 69.225 | 0.241 | Flow ratio | $X_4$ |

Note : Weight* = % of variance of PCs / % of total variance

ISI equation is developed based on Equation (3.5) using all indicators remaining within the components with eigenvalue $\geq$ 1.2. The ISI formula for each of zone is expressed as follows:

$$ISI = 0.259Y_{(X1)} + 0.252Y_{(X2)} + 0.248Y_{(X3)} + 0.241Y_{(X4)} \quad (4.2)$$

Where:
Y = Score of indicator
$X_1$ = Perception of drained water quality
$X_2$ = Satisfaction on adequacy of water distribution
$X_3$ = Net farm income
$X_4$ = Flow ratio

The ISI equation (4.2) is used to determine the ISI of each zone as shown in Table 4.20. The key indicators influencing the sustainability of irrigation in PPP are as follows; only one from physical, socio-economic, institution and environmental indicators. The relationships of each indicator are discussed in following paragraph.

The indicator of first component has the highest variance of 17.90% of total variance with a positive loading. Though the perception of soil quality has loading factor higher than the perception of drainage water quality, the latter plays an important role in terms of environmental indicator. This is due to the fact that the farmer also uses drainage water for irrigation in water scarce areas such as downstream of zone 10 and 11. Moreover, zone 11 is not serviced by the canal network. Thus, perception on water quality is considered as the key indicator of the component. The PPP, farmers pump water to their plots and then excess water flows to the drainage way. Thus drainage water is contaminated with fertilizer, weedicide and pesticide. This indicates that the perception of farmer on the quality of water used for agriculture concern the water quality of drain flow from the field. It is assumed that farmers use pesticide and fertilizer properly that is also safer for environment. Therefore, the higher the farmer perception on drainage water quality from the field, the higher sustainability of the irrigation system.

The second component which influences the sustainability of the irrigation system is the satisfaction on adequacy of water distribution which has 17.41 % of total variance with a positive loading. The adequacy of water in this study means adequacy of amount of water distribution to individual farms during the irrigation season. This indicator indicates that the delivery of water is not adequate and equitable during season. Farmers however do not receive equivalent share of water, in accordance with their actual areas. The PPP has no irrigation process planning and weekly plan but it has a pre-seasonal plan (yearly plan) for water allocation in the project. The seasonal plan is based on official assumptions about the cropping calendar and the gate operating rules in this project are vague. RID staffs do not follow the rule and they operate the system based on their own experiences. However, it seems to have no problem on water distribution, even it does not provide equitable distribution of water. According to Vandersypen et al. (2005), inadequacy water management might lead to unequal access to irrigation water, conflicts over water distribution and deterioration of infrastructure. Hence, the adequacy of water distribution is considered as an important indicator which affects the sustainability of irrigation.

The third component explains 17.20% of total variance with a positive loading. Farm income and net farm income represent the socio-economic indicators group. In this study, net income is considered as an indicator of this component. According to MAF (1997) ; Smith and McDonald (1998); Stockle et al. (1994) cited in Zhen and Routray (2003), the net income is an indicator to assess sustainability of agriculture. The selling price of a product and production cost reveal that the net farm income influences to sustainability of irrigation system. Net farm income is a value obtained by subtracting the selling price of product from the production cost. Production cost involves the cost of a) farm input cost such as seed fertilizer, pesticide and herbicide, other materials, pumping, land renting b) labor cost such as land preparation, seeding and planting, harvesting c) transportation. The selling price of rice depends on trader and the moisture content of rice.

The fourth component that influences to sustainability of irrigation system is flow ratio. It explains 16.713% of total variance with positive loading. The flow ratio indicates how delivered and planned flows match. This indicator explains that if flow ratio is high, it means too much water being supplied. On the other hand, if it low indicates that amount of water is not enough for distribution. This indicator shows the higher flow ratio, the higher sustainability of irrigation system.

To standardize the raw data of key indicators (Table E-9), Equation (3.7) is used to convert them into 0 to 1 scale as shown in Table E-10. Then Equation (4.2) is used to calculate ISI as shown in Table 4.20.

Table 4.20 Irrigation Sustainability Index (ISI) for PPP

| Zone | $X_1$ = Perception of drained water quality | $X_2$ = Satisfaction on adequacy of water distribution | $X_3$ =Net farm income | $X_4$ = Flow ratio | ISI | ISI_class |
|---|---|---|---|---|---|---|
| 1 | 0.235 | 0.171 | 0.172 | 0.132 | 0.710 | 1 |
| 2 | 0.209 | 0.229 | 0.195 | 0.219 | 0.852 | 5 |
| 3 | 0.235 | 0.171 | 0.211 | 0.176 | 0.793 | 3 |
| 4 | 0.176 | 0.171 | 0.147 | 0.219 | 0.715 | 1 |
| 5 | 0.235 | 0.171 | 0.163 | 0.176 | 0.789 | 3 |
| 6 | 0.176 | 0.171 | 0.166 | 0.132 | 0.690 | 1 |
| 7 | 0.118 | 0.229 | 0.226 | 0.132 | 0.704 | 1 |
| 8 | 0.176 | 0.229 | 0.157 | 0.219 | 0.781 | 3 |
| 9 | 0.235 | 0.171 | 0.191 | 0.219 | 0.817 | 4 |
| 10 | 0.217 | 0.171 | 0.162 | 0.219 | 0.770 | 3 |
| 11 | 0.235 | 0.171 | 0.208 | 0.132 | 0.747 | 2 |

The key indicators are different between the two projects. The only one common indicator to both systems is net farm income. The specific indicators for KPP are awareness on irrigation water use, matching of farm operations with RID water delivery, and field application ratio. Perception of drained water quality, satisfaction on adequacy of water distribution and flow ratio on the other hand, are the specific indicators for PPP. This can be explained by the fact that KPP shows a diversity of crops such as rice, sugarcane, vegetable and fruit, while rice is the main crop in PPP. Also cropping pattern of rice is different: KPP is double-cropped while PPP is cultivated five times every two year. For the irrigation deliveries, KPP and PPP have pre-season plans, but unlike KPP, PPP has no weekly plan. Furthermore, farmers in KPP use irrigation water whereas some farmers in PPP use drainage water.

## 4.3 Irrigation Sustainability Map

The ISI equation derived from this study is used to classify the sustainability of each irrigated area (zone) into five levels. Irrigation sustainability map is created to provide a better visualization of the areas that have different levels of irrigation sustainability using GIS technique.

### 4.3.1 Irrigation sustainability map for KPP

The ISI for KPP is categorized into five classes such as very high, high, medium, low and very low using class interval (equal) approach as shown in Table 4.21. The higher index scores mean better irrigation sustainability within the interesting zone. Figure 4.1 shows the locations of the zone that have level of sustainability irrigation in KPP.

Table 4.21 Irrigation Sustainability Class in KPP

| Classification Score | Index Interval | Sustainability of Irrigation |
|---|---|---|
| <0.645 | 1 | Very low |
| 0.645-0.710 | 2 | Low |
| 0.711-0.776 | 3 | Medium |
| 0.777-0.842 | 4 | High |
| >0.842 | 5 | Very High |

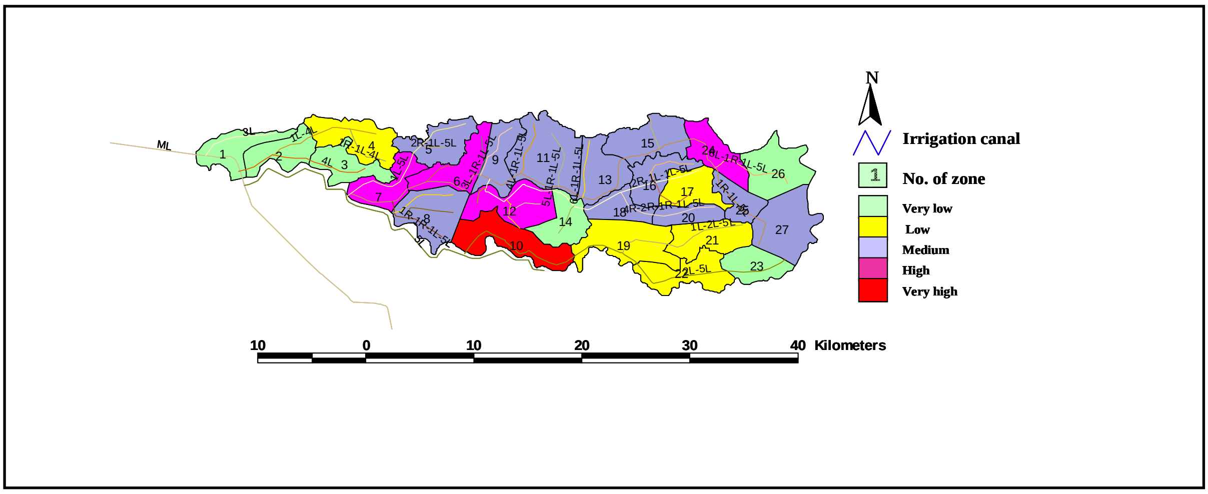



Figure 4.1 Irrigation sustainability map of KPP

Figure 4.1 shows the irrigation sustainability map based on ISI Equation (4.1) that was developed in this study. There are six zones that show very low sustainability (zone 1, 2, 3, 14, 23 and 26), five zones have low sustainability (zone 4, 17, 19, 21 and 22), 11 zones that have average sustainability (zone 5, 8, 9, 11, 13, 15, 16, 18, 20, 25 and 27) and another four zones that have high sustainability (zone 6, 7, 12 and 24). Zone 10 is the only area in KPP that has very high sustainability.

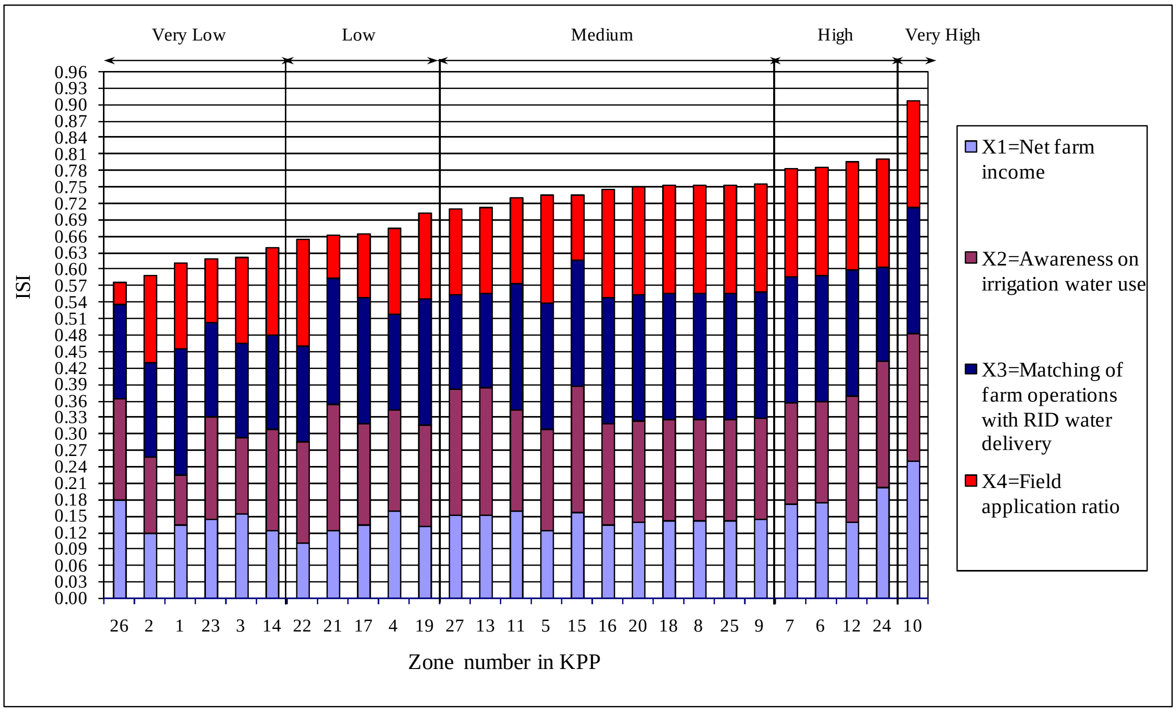



Figure 4.2 Contribution of indicators to ISI for each zone in KPP

Figure 4.2 shows the relative effects of different key indicators on irrigation sustainability for each zone. Four indicators are found in KPP; net farm income is the most dominant indicator followed by awareness on irrigation water use, matching of farm operations with RID water delivery and field application ratio. This is further explained below.

The net farm income in zone 1 is low despite high crop yield and selling price. The low value of the net farm income is due to high production costs. In zone 2, the net farm income is low despite high crop yield. The low net farm income is attributed to the low selling price of the crops and high production cost. Net farm income in zone 24 and 26 are high because of high crop yield, high selling price and low production cost.

Awareness of irrigation water use in zone 1, 2 and 3 is low because these zones are located in the upstream section. These farmers are the first to receive irrigation water from the canal. Such situation makes the farmers unaware of the importance of proper management of irrigation water. Zone 6, 17, 19, 21, 24 and 27 show high level of awareness because they are located in the downstream section. Farmers in these zones received less water especially during dry season. This situation forces farmers to optimize water use under limited supply of irrigation water. This implies that the farmers are practically adopting deficit irrigation system under limited water conditions.

Matching of farm operations with RID water delivery in zone 2, 3, 13, 14, 22, 26 and 27 are low due to the diversity of crops such as rice, sugarcane, vegetables and fruits. In these zones, the planting period does not correspond with water delivery. The indicator is very high in zone 1, 8, 16, 17, 18, 19, 20 and 25 where the main crop is rice. The indicator is also high in zone 5, 10 and 15 despite the diversity of crops. The high level of this indicator in these zones can be attributed to the presence of zonemen, who are operating the system as equitable as possible and according to needs even during critical periods.

Field application ratios of zone 21, 23 and 26 are low because the actual cultivated areas are higher than the RID official planned areas. Hence, the estimated irrigation water requirement does not match the actual withdrawal. Aside from the estimation difference, the location of the zones can also affect the field application ratios. For example, zone 21, 23 and 26 are located in the downstream area where there is no additional canal that can help in supplying irrigation water. This situation brings risk to the mentioned zones especially during critical periods. However, the field application ratios are high in some zones in the upstream and downstream sections. For instance, zone 7, 9, 10 and 12 are located upstream and they receive adequate water from main irrigation canal. Zone 5, 6, 16, 18 and 24, on the other hand, are served by tertiary canals that can supply enough water even they are located at the downstream section.

### 4.3.2 Irrigation sustainability map for PPP

The ISI for PPP is categorized into 5 classes such as very high, high, medium, low and very low using class interval (equal) approach as shown in Table 4.22. The higher index scores mean the better irrigation sustainability of that zone.

Table 4.22 Irrigation Sustainability Class in PPP

| Classification Score | Index Interval | Sustainability of Irrigation |
|---|---|---|
| <0.725 | 1 | Very low |
| 0.725-0.760 | 2 | Low |
| 0.766-0.795 | 3 | Medium |
| 0.796-0.830 | 4 | High |
| >0.830 | 5 | Very High |

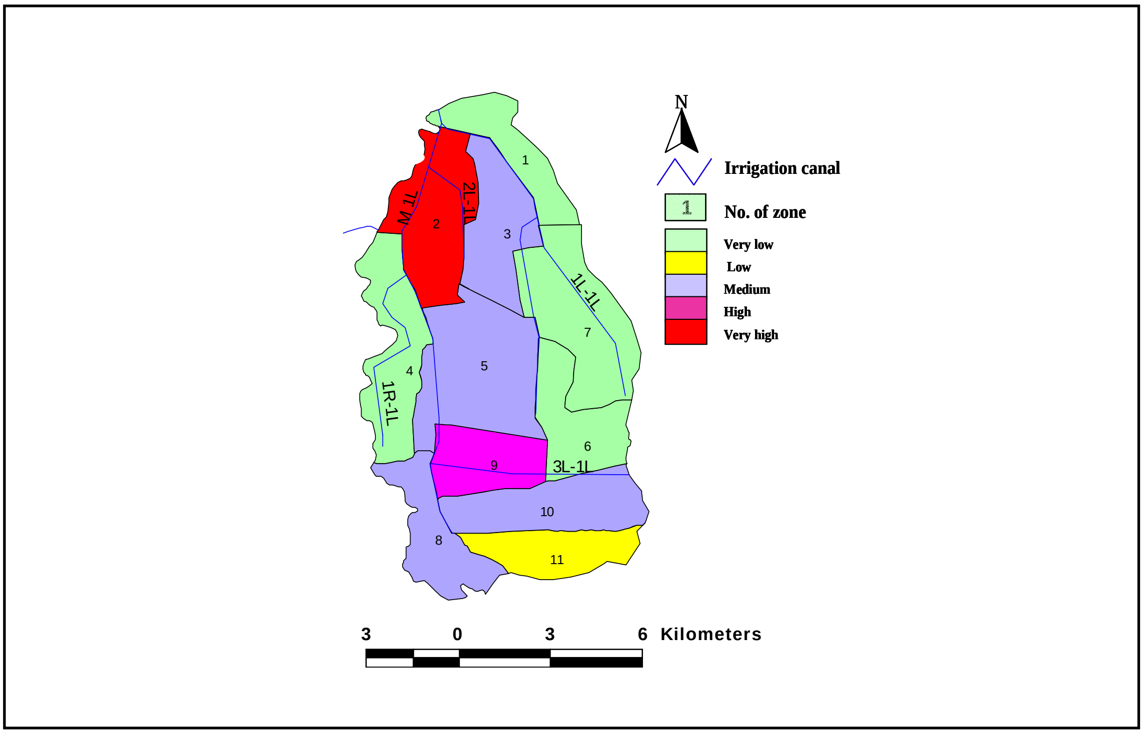



Figure 4.3  Irrigation sustainability map of PPP

Figure 4.3 shows the irrigation sustainability map based on ISI equation (4.2) that was developed in this study. There are four zones showing very low sustainability (zone 1, 4, 6 and 7), one zone has low sustainability (zone 11) and four zones have average sustainability (zone 3, 5, 8, and 10). Zone 9 and 2 have high and very high sustainability respectively.

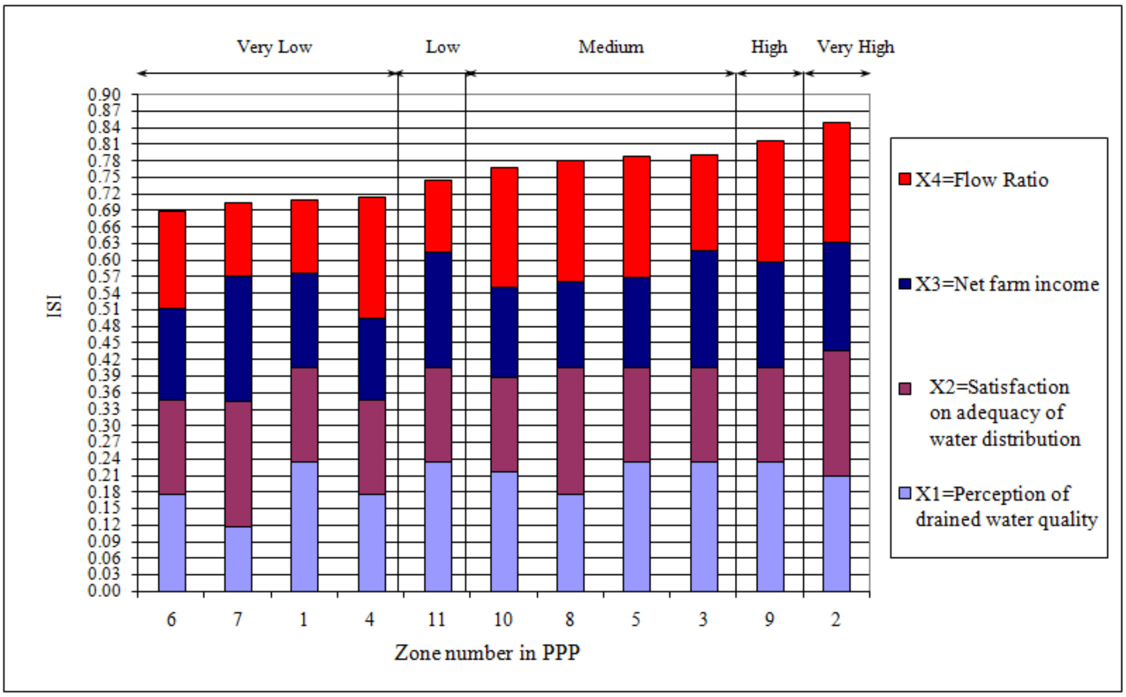



Figure 4.4  Contribution of indicators to ISI for each zone in PPP

Figure 4.4 shows the relative effects of different key indicators on irrigation sustainability for each zone. Four indicators are found in PPP; perception on water quality is the most dominant indicator followed by satisfaction on adequacy of water distribution, field application ratio and net income. This can be explained as follows;

Farmers in zone 4, 6, 7 and 8 are moderately aware of drained water quality from their fields. They also have poor knowledge on irrigation water management. In addition, farmers who use water from drainage canal are more aware of drained water quality than those using irrigation canals. For example, zone 10 and 11 are located outside the service areas. Hence they are compelled to use water from the drainage system.

Farmers in zone 1, 3, 4, 5, 6, 9, 10 and 11 are moderately satisfied on the adequacy of water distribution. Average satisfaction means that some farmers are able to meet the irrigation water demand of their crops while some farmers demand an equal sharing of irrigation water. Farmers in zone 2, 7 and 8 on the other hands, are satisfied on the supply of irrigation water to their respective fields.

The net farm income in zone 1 and 4 are low despite good crop yield and high selling price. The low value of the net farm income is due to high production costs. In zone 5 and 8, the net farm income is low despite low production costs and good crop yield. The low net farm income is attributed to the low selling price of crops. Net farm income in zone 2, 3, 7, 9 and 11 are high because of the high selling price, good crop yield and low production costs. The selling price depends on the moisture content of rice and the presence of rice mills which are located at different places in this project.

Flow ratio in zone 1, 6, 7 are low because these zones receive water from secondary canal. Zone 2 and 4, on the other hand, show high flow ratio because they receive water from main canal. In PPP, there is no weekly plan for water allocation. Zonemen operate the gate based on their experiences thus they may allocate insufficient water to secondary canal as mentioned above.

The above findings have demonstrated that indicators influencing sustainability varied from zone to zone or from one project to another. This shows that each zone or project can be vulnerable to different indicators influencing irrigation system.

### 4.4 Strategies for Improving Irrigation Management

Based on the key factors identified and obtained from the two projects, it can be concluded that socio-economic, institutional and physical factors play a major role in the sustainability of the irrigation system in Tha Chin Basin. Although, the factor from environmental group does not show in this study, it does not mean it is not important. It could be because not enough data were available and they were not high correlated (variance) i.e. soil property (EC) and irrigation water quality (EC) therefore, they were not considered in PCA analysis. Table 4.23 and 4.24 show key factors, problem and the strategies to manage irrigation system in KPP and PPP respectively.

Table 4.23 Problems with Key Factors, and Suggested Strategies in KPP

| Factor | Key Factors/Indicator | Problems | Strategies |
|---|---|---|---|
| Physical | Drainage ditch condition (clean/smooth) | Some area can not drain water to the drainage system. | - Clean and clear drainage system before irrigation season<br>- Construction of drainage way<br>-Encourage farmers to participate |
| | Ditch condition (clean/smooth) | Water can not flow through tail end because there is presence of sediment, grass and weed. | -Maintain or repair ditch before irrigation season starts<br>- Encourage farmers to participate |
| Socio-economic | Experience of farmer | When to plant, when and how much to fertilize and when to harvest are not clear to farmers | -Educating and training farmers to provide knowledge on new technologies and water saving |
| Institutional | Work load | Work load is not balanced because the numbers of staffs in each zone are not equal. | - Share the staff between zone boundary |
| | Satisfaction on planning of water delivery schedule by RID staffs and WUG | The farm practices do not correspond to water delivery scheduling | - Improve scheduling of water delivery |
| | Reliability of continuous flow during the irrigation season | No rules and regulations to divert water and punishment for those who break these rules.<br><br>Inadequate amount of water and time for irrigation. | -Establishment of rules and regulations<br><br>-Set guideline for water distribution |

Table 4.24 Problems with Key Factors, and Suggested Strategies in PPP

| Factor | Key Factors/Indicator | Problems | Guidelines |
|---|---|---|---|
| Physical | Drainage ditch condition (clean/smooth) | Some area can not drain water to drainage system. | - Clean and clear drainage system before irrigation season<br>- Construction of drainage way<br>-Encourage teamwork among water users<br>-Cooperating with local government for budget support<br>-Promote participation and awareness of farmers |
| | Ditch condition (clean/smooth) | Water can not flow through tail end because there is sediment, grass and weed in irrigation canals | - Maintain or repair ditch before the irrigation season start<br>- Encourage teamwork among water users<br>- Cooperating with local government for budget support<br>- Promote participation and awareness of farmers |
| Socio-economic | Production cost | High production cost because farmers use machine instead of manual labor<br><br>Intensive fertilization | - Decrease inputs such as fertilizer application<br>- Use manual labor instead of machine<br>- Promote mutual help during land preparation and harvest time |
| | Experience of farmer | When to plant, when and how much to fertilize and when to harvest are not clear to farmers | - Educating and training farmers to provide knowledge on new technologies, water saving, etc |
| Institutional | Number of Staff | Number of staff are not uniform throughout the system | - Share the staff between zone boundary |
| | Satisfaction on cultivated areas are surveyed by WUG before irrigation season | The crop area is assumed (instead of the surveyed crop area) to find the water requirement which may not match with the real water use | -Survey crop area before irrigation season |
| | Satisfaction on accountability of timeliness and fairness of water distribution | Farmers are not able to maintain equity of water sharing | - Enhance relationship between zoneman and water users<br>- Give information about water delivery via water users leader |

### 4.5 A Framework for Sustainable Irrigation Management

The Driving forces-Pressures-State-Impacts-Response (DPSIR) framework developed by the European Environment Agency (EEA) is useful in describing the relationships between the origins and consequences of environmental problems and it is also useful to focus on the links between DPSIR elements. According to the definitions of EEA (1999), the driving forces (D) are the human activities causing an environmental problem. The pressures (P) refer to the level and source of pressure. The state (S) describes and quantifies the extent of the current problem e.g. amount of soil erosion and soil contamination. The impacts (I) indicate the effects of the problem on creating further problems e.g. land productivity loss and biodiversity loss. The responses (R) are the strategies to solve or minimize the problems.

This study modified and used this framework as an analytical approach to help to understand the cause-effect relationship among interacting components of numerous factors e.g. physical, socio-economic, institutional and environmental indicators influencing sustainable irrigation management. The modified DPSIR framework which is specifically applied to irrigation management includes the following features;

- The Driving forces (D) are the underlying anthropogenic causes affecting the sustainability of the irrigation system (e.g. farmer experience).

- The Pressures (P) are the outcome of the driving forces influencing the current situation. It also represents the specific translations of driver into the study site (e.g. farmer practice).

- The State (S) assesses the current status of problems (e.g. low field application ratio).

- The Impacts (I) refers to the effects of the problems identified (e.g. low net farm income).

- The Responses (R) relates to the management options or the strategies to solve or minimize the problems or their causes (e.g. improvement of water distribution schedule).

Figures 4.5 and 4.6 show strategic planning of irrigation management based on key indicators for KPP and PPP in term of factors common to both projects and factors specific to each project. Furthermore, the DPSIR framework was applied to improve irrigation management in KPP and PPP based on key indicators influencing sustainability of irrigation, field observations and socio-economic survey. These frameworks are presented in Figure 4.7 and 4.8.

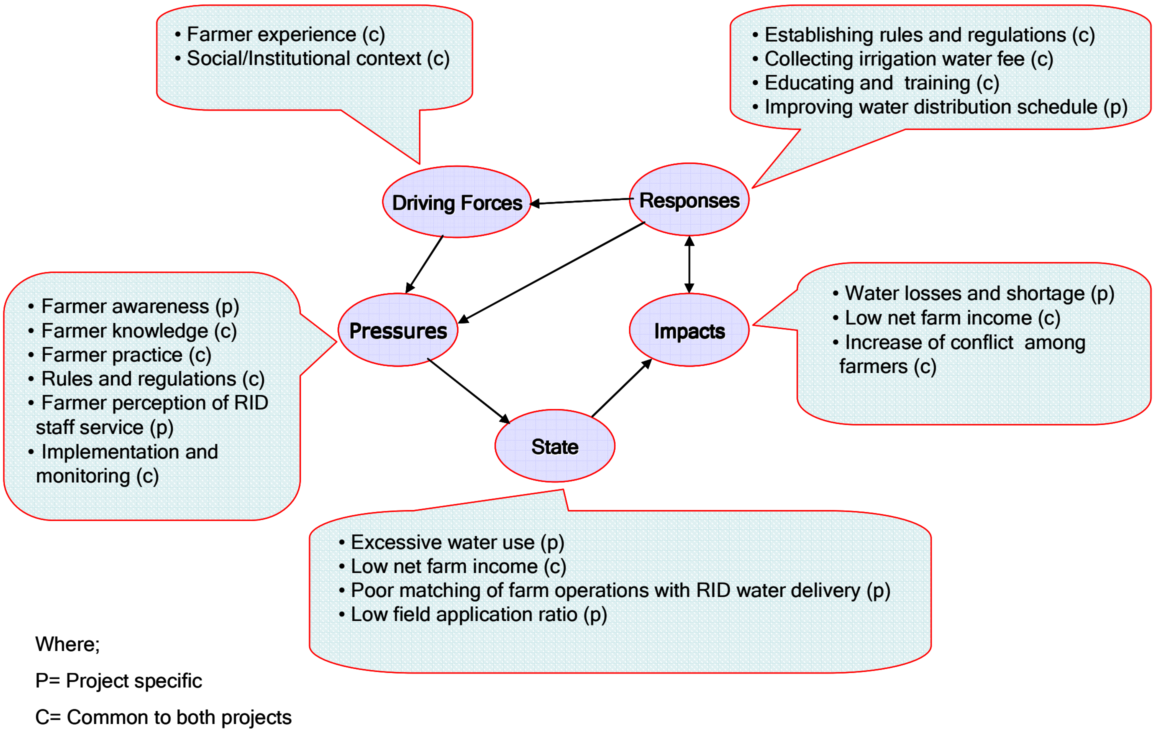



Figure 4.5 Strategic planning of irrigation management based on key indicators for KPP

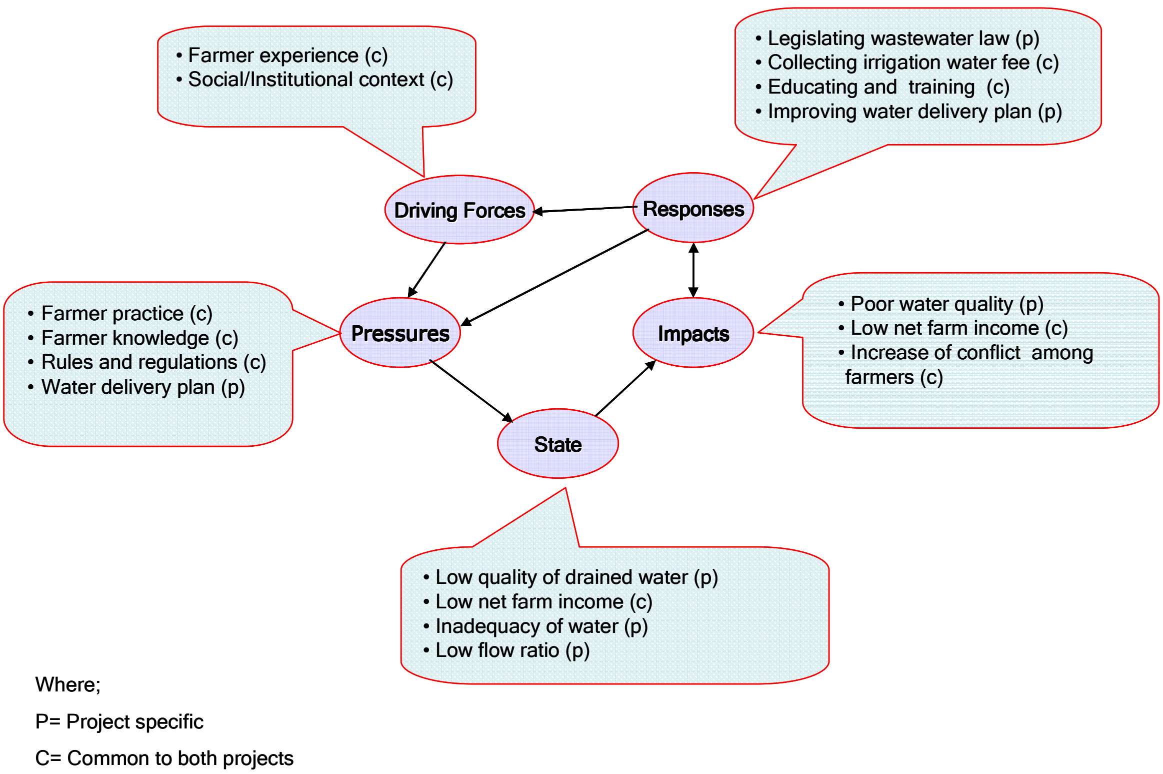
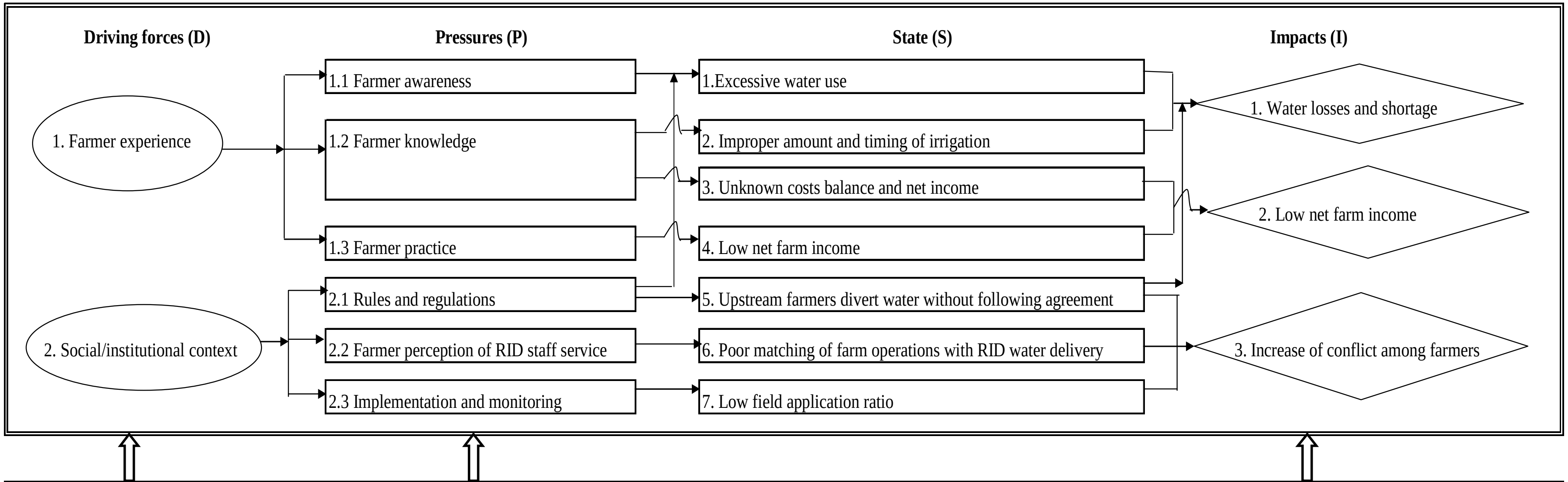
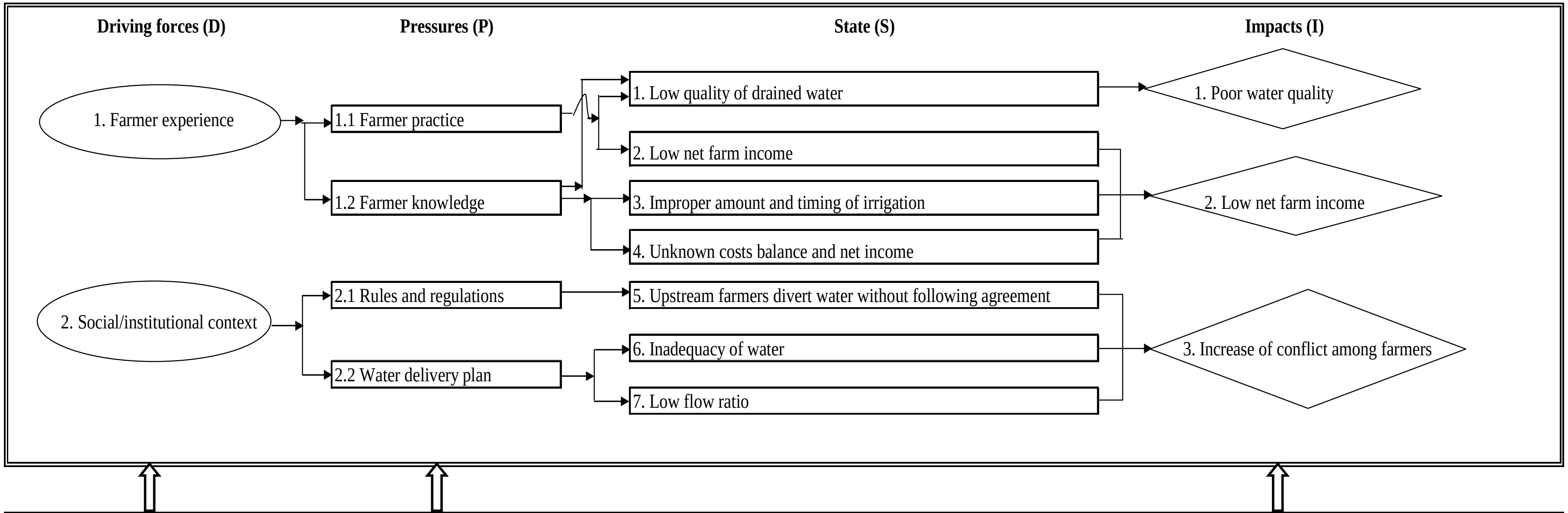



Figure 4.6 Strategic planning of irrigation management based on key indicators for PPP




| **( R ) Responses; Policy and management options for ( D ),( P ) and ( I )** | | **Level of response** |
|---|---|---|
| 1) Establishment and strengthening of water user groups (1 D), (2 D), (1.1 P), (2.1 P), (1 I), (3 I)<br>2) Provision of support services and promotion of mutual assistance (1 D), (1.3 P), (2 I) | 3) Establishing rules and regulations on water use (2 D), (1.1 P), (2.1 P), (1 I), (3 I) | **On farm level** |
| 1) Enhance awareness and attitude of farmers on water use efficiency (1 D), (1.1 P), (1.2 P), (1.3 P), (1 I), (3 I)<br>2) Education and training of farmers (1 D), (1.1 P), (1.2 P), (1.3 P), (1 I), (3 I)<br>3) Teaching economic or financial management (1 D), (1.2 P), (1.3 P), (2 I)<br>4) Encouraging farmers to change farming practices (2 D), (2.2 P), (3 I) | 5) Improving of water distribution schedule (2 D), (2.2 P), (2.3 P), (3 I)<br>6) Training RID staff (2 D), (2.3 P), (3 I)<br>7) Calibration or check the functions of structure (2 D), (2.3 P), (3 I) | **Project level** |
| 1) Collecting irrigation water fee (1 D), (1.1 P), (1 I), (3 I)<br>2) Encouraging farmer participation in irrigation management (1 D), (2 I), (1.1 P), (1 I), (3 I) | 3) Provision of external support for rehabilitation (1 D), (2 D), (1.2 P), (2.3 P), (1 I), (2 I), (3 I) | **RID level** |

Figure 4.7 A modified DPSIR framework for irrigation management of KPP




| **( R ) Responses; Policy and management options for ( D ),( P ) and ( I )** | **Level of response** |
|---|---|
| 1) Establishment and strengthening of water user groups (2 D), (2.1 P), (3 I)<br>2) Provision of support services and promotion of mutual assistance (1 D), (1.1 P), (2 I)<br>3) Establishing rules and regulations on water use (2 D), (2.1 P), (3 I) | **On farm level** |
| 1) Promotion of organic fertilizer (1 D), (1.1 P), (1 I), (2 I)<br>2) Monitoring drainage water quality (1 I)<br>3) Educating and training farmers (1 D), (1.1 P), (1.2 P), (1 I), (2 I), (3 I)<br>4) Teaching economic or financial management (1 D), (1.1 P), (1.2 P), (2 I)<br>5) Training RID staff (2 D), (2.2 P), (3 I)<br>6) Improving irrigation water delivery plan (2 D), (2.2 P), (3 I)<br>7) Improving flow measurement (3 I) | **Project level** |
| 1) Legislating agricultural wastewater law or act (1.1 P), (1 I)<br>2) Collecting irrigation water fee (1D), ( 3 I)<br>3) Provision of external support for rehabilitation (1 D), (2 D), (1.2 P), (1 I), (2 I), (3 I) | **RID level** |

Figure 4.8 A modified DPSIR framework for irrigation management of PPP

### 4.5.1 Modified DPSIR framework for irrigation management in KPP

Within this framework a flow diagram was developed showing interrelationships between the DPSIR components and describing the cause effect relationship among the numerous physical, socio-economic, institutional and environmental indicators. Each of the elements within this management framework is illustrated in Figure 4.7 and discussed below.

**Driving forces and pressure (D, P)**

***1) Farmer experience;*** this refers to awareness of farmer on water use, knowledge of farmer and farmer practice. These are explained below.

***1.1) Farmer awareness;*** farmers have poor awareness on water use especially water supply for crops. They are unaware of irrigation water use that has resulted in excessive water usage. Therefore, the cause of irrigation water wastage is poor awareness of farmers on water use.

***1.2) Farmer knowledge;*** this explains the knowledge and skill of farmers in term of growing, harvesting and cost balancing. The good knowledge about planting of farmers shows that they know the proper amount of water and timing of growing season, how to take care of the crops planted and when to harvest. For knowledge in term of cost balancing, it also helps farmers to analyze the problem and identify appropriate change in order to improve their farms management and income. They lack knowledge on water use and economic or financial management. Farmers endeavor to optimize water supply of their crops based on the limits of their knowledge and the farming operation practiced. These situations bring them to face water losses and shortage. They also have never recorded their input use, expenditure, yield and income. Therefore, they do not know the balanced costs and net income for planning on next season.

***1.3) Farmer practice;*** this explains fertilizer and pesticide application of farmers. The good practices of farmers show that they know the better pest, disease and weed control method that farmers will use and how much to fertilize. Farmers apply excessive fertilizer, weedicide and pesticide during growing crops. Therefore, this factor influences to production cost and translates to net farm income.

***2) Social/institutional context;*** this refer to the official work, relation between farmers and RID staff and management in the project. These involve rules and regulations, farmer perception of RID staff service and implementation and monitoring. These are explained below.

***2.1) Rules and regulations;*** the basic behavior of farmers is to take maximum advantage of diverting water to their fields ignoring gate operation and farming plan. The rules and regulations in this project have many deficiencies. There is the draft that describes how to allocate the service share, how much money to pay for WUG and the punishment for the farmer who breaks this agreement. Conversely, the farmers are unaware of their responsibility and right in the irrigation project. The relation of water user groups is not strong and nobody wants to be a substitute for responsible water management. Although KPP has a draft document for WUG, farmers ignore to follow and establish the regulations for them. RID officials describe the understanding but do not take plans to follow up. Therefore, farmers divert water to their plots without regulation rules hence they face conflict between upstream and downstream farmers.

***2.2) Farmer perception of RID staff service***; the important factors which affect the matching of farm operations with RID water delivery in KPP are farm operations of farmers and water delivery of RID. Farmers do not follow the cropping pattern and water delivery schedule; they grow many varieties of crops; for example, rice, sugarcane and asparagus which have different water requirements depending on their stage of growth. Therefore, distribution in KPP is complex and difficult to manage. These affect to match of farm operations and water delivery in KPP. Moreover, the gate operation is designed based on top-down. Therefore, the operation period does not match with water delivery schedule in KPP.

***2.3) Implementation and monitoring;*** these refer to implementation and monitoring of water delivery. There is stipulation of water delivery plan for RID staff but RID staff and water users group (WUG) do not follow the activity of water delivery (e.g. surveying crops cultivated, calculation of water requirement, information of agreement on water delivery plan to water users group and its member, water measurement and evaluation of adequacy of water distribution). Zonemen do not collect information on crops cultivated and they estimate crop water requirement by themselves. After water delivery, they do not compare the measured discharge to water delivery plan. Therefore, water delivery is not according to crop requirement.

**State (S)**

The state of sustainability irrigation in KPP can be described for the current situation or problems as below.

***1) Excessive water use****;* The farmers divert irrigation water to their plots without regard to time and the amount of water delivery. They divert water to their rice fields and then water exceeds through their fields to the other area. Awareness of irrigation water use in zone 1, 2 and 3 are low because these zones are located in the upstream side. These farmers are the first to receive irrigation water from the canal. Hence, they can use any amount of irrigation water because there is no rule and regulation to punish the farmers who break these agreements and they do not pay for irrigation fee. This scenario shows that the farmers do not concern about the importance and management of irrigation water.

***2) Improper amount and timing of irrigation;*** *The* farming is passed on from one generation to the next hence the farmers do not have sufficient knowledge and skill. Normally farmers use their own senses to determine when and how much water to irrigate. Education level of farmers in the KPP was found low, farmers in KPP have educational level at elementary (85.7%) and experience of them between 26-35 years was found to be 67.1% (for more details see Table 3.24 and 3.26).

***3) Unknown costs balance and net income;*** Farmers never recorded their input use, expenditure, yield and net income. They are in debt of fertilizer and insecticide etc. and they will pay after harvest. Therefore, they do not know the cost balance for planning on next season.

***4) Low net farm income***; The net farm income in zone 1 is low despite its high crop yield and selling price. The low value of the net farm income is due to the high production cost. In zone 2, the net farm income is low despite of their high crop yield. The low net farm income is attributed to low selling price of crop and its high production cost. (for more details see Table 3.31 and 3.33). The cost of land preparation, broadcasting, fertilization, harvesting and transportation are expenses which affect the production cost in this project. In some cases mutual help between the farmers can reduce the labour cost (e.g. land preparation and harvesting). The selling price of rice which influences farm income is dependent on moisture content of rice, so farmers need to have basic knowledge on determining right moisture content before selling.

***5) Upstream farmers divert water without following agreement;*** The upstream farmers divert irrigation water to their plots without regard to time and the amount of water delivery. They can use any amount of irrigation water because there is no rule and regulations for water sharing. Hence, down stream farmers receive insufficient water. This situation brings conflict among farmer (see Table D-6).

***6) Poor matching of farm operations with RID water delivery;*** Matching of farm schedule practice and water delivery based on agricultural operation calendar of the KPP in zone 2, 3, 13, 14, 22, 26 and 27 are low. In these zones, the planting period is not associated with the operation of water delivery because there is the diversity of crops like rice, sugarcane, vegetables, fruits etc. The farmers do not follow the cropping pattern and gate operating of project. The agriculture operation is designed based on Top-Down approach. Therefore, the operation period does not match with schedule practice in KPP. Example of this situation explained that the irrigation system is operated during 5$^{th}$ February to 4$^{th}$ June for the dry season and 16$^{th}$ July to 3$^{rd}$ December for the wet season. During such operation crop like asparagus and farmers who plan for 3 crops of rice in a year do not get enough water thus water distribution in KPP is difficult to manage. Therefore, some conflicts occurred and fighting among farmers for water during drought.

***7) Low field application ratio****;* The field application ratios are low because the applied water is less than water requirement. The actual planted areas are more than the RID planned areas and the official cropping calendar is not corresponding to the real agricultural activities of farmers. Hence, the estimation of the amount of irrigation water did not match with the actual withdrawal. Moreover, the water requirement of weekly plan is constant meaning that official staffs do not calculate the crop water requirement based on the actual data (see Table A-19). In addition, the location of the zones can also affect the field application ratios. For example, zone 21, 23 and 26 are located in the downstream area (see Figure 4.1 and Table 3.18). At this location, there are no additional canals that supply water.

**Impact (I)**

There are several conditions that may severely threaten the sustainability of irrigation system as below:

***1) Water losses and shortage*****;** Farmers use excessive water because they have poor awareness of irrigation water use. They lack knowledge about the proper period for irrigation and how much water to apply. Moreover, there is an apparent lacking of rules and regulations to punish the farmers who break this agreement. For such reasons excessive water use, limited knowledge of farmers and lack of rules and regulations can result to water losses and shortage.

***2) Low net farm income*;** The low value of the net farm income is due to high production costs, low crop yield and low selling price of crops. The production costs involve the total costs of seeds, fertilizers, pesticides, land preparation, seeding, harvesting and transportation, etc. Crop yield is low due to low field application ratio. Selling price depends on the moisture content of rice and the presence of rice mills which are located at different places in this project. These cause the net farm income to be low.

***3) Increase of conflict among farmers;*** The upstream farmers divert irrigation water to their plots without the time constraint and the amount diverted and also without following the regulation and rules. However, there is no rule or regulation to punish the farmers who break the water sharing agreement. This situation creates conflict among farmers.

**Responses (R)**

The study suggests a suitable guidance and implementation for sustainable irrigation management. These involve improving and raising the awareness of irrigation water use, adequacy of water distribution, farm income and field application ratio in KPP and guidelines also taking into account economic, technical environmental and social aspects. According to Palayasoot (2007), practice of water management of an irrigation system can be categorized into three levels of response i.e. on farm level, project level and water source level. The following guidelines are recommended.

**a) On farm level**

KPP is separated into 27 irrigated areas (zones). Each zone will organize the water user groups in each service unit. Water user sub-groups have been established according to the ditch sector within the service unit. Each water user group selects its own ditch leader who acts as irrigator and contacts farmer. Zoneman is responsible to water delivery and surveying of crop yield and crop area. Gate tender is responsible for the structure e.g. headwork, cross-regulator or regulator. They have hours near the zone boundary. The responses at on farm level are as follows.

1) Establishment and strengthening of water user groups include a clear definition of their roles in the irrigation water supply and development working relationship, responsibility and management of water user groups on lateral and sub-lateral canal e.g. sewage cleaning, repair, grass cutting and cost sharing.

2) Provision of support services and promotion of mutual assistance;

a. Provision of support services such as agricultural credit, market information, agricultural extension of support service and agricultural inputs.

b. Promotion of mutual assistance and pooling of equipment such as rice transplanter, power tiller, pump etc. during land preparation, transplanting and harvest time to reduce production cost.

3) Establishing rules and regulations on water use, it is necessary to clearly define water right and motivates the responsibility of farmer on irrigation water use. Enforcement mechanisms must be introduced to ensure efficiency and to address water use.

**b) Project level**

There are the O&M staff and organizations existing in RID to take care of irrigation facilities of O&M. The project engineer will be responsible for the overall project water management. The water master is responsible for the water management in the sub-divided main canals and instruction to the zoneman. The continuous flow system in main canal and lateral canal are common water management. The following guidelines are recommended.

1) Enhance awareness and attitude of farmers on water use efficiency and in farm water resources planning and management.

2) Education and training of farmers on crop water requirement (when and how much water to supply), efficient water use and water saving.

3) Teaching economic or financial management is necessary to make farmer understand cost balancing. Profitability analysis program is a procedure for diagnosing a farm profitability problem (for more details see Chapter 2). Encourage the farmers to keep a record of the farm account for example; their input use, expenditure, yield and income. This record that will give information needed to determine the best combination of various enterprises and the proper use of farm credit. The record keeping is useful for complete farm planning, budgeting and farm management. It helps a farmer to analyze the problem and identify appropriate change in order to improve his farm management and income.

4) Encouraging farmers to change crop zoning and timing of cultivation to maximize water allocation and promote rice drying to maintain quality of rice grain to increase its selling price. Moreover, reasonable of selling the product until the market is more favorable to get price and better income.

5) Improvement and flexibility of water distribution schedule of the project are considered e.g. decision on the start of crop season, end of the season and extent of the area allocated for irrigation. There should be separate water management unit under the KPP to manage the intake and operate by itself. The responsibility of KPP for implementation on the weekly plan should be clear. The system design, allocation and distribution procedure are made with certain assumptions and approximation.

6) Training RID staffs to improve their performance as well as for effective operations and maintenance of existing irrigation project. This training will lead to change of competence and potential in terms of awareness knowledge, skill, attitudes, etc. The incentives could be monetary or certificate to a laudation staff such as annual prize for the best plan implementation performance.

7) Calibration or check the functionality of structure to assess its efficiency (e.g. calibration of flow at gate regulator) and provide appropriate equipment and technology to monitor and control water delivery efficiently.

**c) Water source level (RIO and RID)**

Regional Irrigation Office 13 (RIO) and RID are responsible for water allocation among the irrigation projects which share common water source and pay much attention in restructuring both the administration aspect and irrigation management.

1) Collection of irrigation water fee is necessary to cover maintenance expense and future rehabilitation and to improve water use efficiency. Based on survey, In KPP, farmers are willing to pay for irrigation water fee at the average rate of 25 Baht/rai/year (see Table D-4).

2) Encouraging farmers participation in an irrigation management as early as the planning phase i.e. project planning, construction and management to enhance farmer's sense of ownership and to improve water use efficiency, to use their rights and to protect and maintain the project in sustainable ways.

3) Provision of external support for major rehabilitation of infrastructure, human and social development, natural resources and environment, economic development, water resource development and administration.

### 4.5.2 Modified DPSIR framework for irrigation management in PPP

Within this framework a flow diagram was developed showing interrelationships between the DPSIR components and describing the cause effect relationship among the numerous physical, socio-economic, institutional and environmental indicators influencing irrigation systems specifically. Figure 4.8 shows modified DPSIR framework for irrigation management of PPP. Each of the elements within this management framework is discussed below.

**Driving forces and pressure (D, P)**

***1) Farmer experience;*** this refers to farmer practice and knowledge of farmer. These are explained as below.

***1.1) Farmer practice;*** this explains fertilizer and pesticide application of farmers. The good practices of farmers show that they knows the better pest, disease and weed control method that farmers will use and how much to fertilize. Farmers apply excessive fertilizer, weedicide and pesticide during growing rice which can be planted five times per two years. Therefore, this factor influences production cost and translates to net farm income and lead to drained water quality.

***1.2) Farmer knowledge;*** this explains the knowledge and skill of farmers in term of growing, harvesting and cost balancing. The good knowledge about planting of farmers shows that they know the proper amount of water and timing of growing season, how to take care of the crops planted and when to harvest. For knowledge in term of cost balancing, it also helps farmers analyze the problem and identify appropriate change in order to improve their farms management and income. They lack knowledge on water use and economic or financial management. Farmers endeavor to optimize water supply of their crops based on the limits of their knowledge and the farming operation practiced. These situations bring them to face water losses and shortage. They also have never recorded their input use, expenditure, yield and income. Therefore, they do not know the balanced costs and net income for planning on next season. Moreover, lack of knowledge on water contamination due to fertilizer and pesticide use; farmers are unaware of quality of drained water from their fields.

***2) Social/institutional context;*** this refer to the official work, relation between farmers and RID staff and management in the project. Rules and regulations, water delivery plan are major concerns. These are explained below.

***2.1) Rules and regulations*** There are no rules and regulations in this project. There is no draft describing how to allocate the service share, how much money to pay for water user groups (WUG) and the punishment for the farmer who break the water sharing. Hence, the farmers are unaware of their responsibility and right in the irrigation project. The relation of water user groups is not strong and nobody wants to be a representative for responsible water management. Farmers divert water to their plots without regulation rules hence they face conflict between upstream and downstream farmers.

***2.2) Water delivery plan***; In PPP, it does not have weekly plan but it has a pre-season planning in both seasons. This plan concerns about allocation of water quantity for the project's entire season. The seasonal plan is based on the officer's assumptions from cropping calendar. The gate operating rules in this project are vague. RID staffs do not follow the rule but they operate based on their experience. This causes to low flow ratio.

**State (S)**

The state of irrigation sustainability in PPP is described in term of the current situation or problems as discussed below.

***1) Low quality of drained water;*** The drained water may be contaminated with fertilizer, weedicide and pesticide. This study does not analyze the water quality from farmer's field at the drainage system but some samplings are taken from drainage canal which farmers use for irrigation (e.g. drainage canal Suphan 3 and Suphan 4). There are two locations in PPP namely; drainage canal Suphan (3-5 R) station 19 and Bangplama (station 22) which show low values of DO (for more detailed see Table A-3 and A-4). Farmers do not care and are not aware of the quality of drained water from their fields. Farmers in zone 7 are unaware of the drained water quality. On the other hand, farmers in zone 4, 6 and 8 are moderately aware about the quality of drained water (for more information see Table D-7). They also have a poor knowledge about preservation of drained water quality and they do not know the agriculture wastewater guidelines. Moreover, there are no laws about wastewater form agriculture practices but there are enhancement and conservation of national environmental quality act B.E. 2535 (for pig farm).

***2) Low net farm income*****;** In this project, land renting and labor costs are the expenses which affect the production cost. The cost for land preparation, broadcasting, fertilization, harvesting and transportation are the normal expenses which all farmers have to spend. In some cases, mutual help between farmers are available which helps cut on labour cost during land preparation and harvesting. The net farm income in zone 1 is low despite good crop yield and high selling price. The low value of the net farm income is due to high production costs. In zone 5 and 8, the net farm income is low despite low production costs and good average crop yield. The low net farm income is attributed to the low selling price of crops. Net farm income in zone 2, 3, 7, 9 and 11 on the other hand, are high because of the high selling price, good average crop yield and low production costs (for more details see Table 3.32 and 3.34).

***3) Improper amount and timing of irrigation****;* Farming is passed on from one generation to the next hence the farmers do not have sufficient knowledge and technical skill. Normally farmers use their own sense to determine when and how much water to irrigate. Education level of farmer in the PPP was found to be low. Farmers in PPP have educational level at elementary (81.93%) and experience of farmers between 15-25 years is found 32.23 % (for more details see Table 3.25 and 3.27).

***4) Unknown costs balance and net income****;* Like KPP, farmers have never recorded their input use, expenditure, yield and net income. They acquire the inputs (e.g. fertilizer, insecticide etc) during growing season with some assurance that they will pay after harvest. Therefore, they do not know the cost balance for planning in the next season.

***5) Upstream farmers divert water without following agreements.*** Farmers divert water to their plots without regulation rules especially upstream farmers they take advantage of upstream location ignoring gate operation and farming plan. The upstream farmers divert freely irrigation water to their plots without regard to time and the amount of water delivery. They can use or waste any amount of irrigation water because there is no rule and regulation to punish the farmer who breaks these agreements.

***6) Inadequacy of water;*** The distribution of water shows that water delivery in PPP is not adequate. Farmers do not receive sufficient amount of irrigation water to their areas. The values of irrigation water requirement do not balance with the actual irrigation water delivery to the fields hence they face inadequate water distribution. Farmers in zone 1, 3, 4, 5, 6, 9, 10 and 11 are moderately satisfied on the adequacy of water distribution. Average satisfaction means that some farmers are able to meet the irrigation water demand of their crops while some farmers demand an equal sharing of irrigation water. Conversely, farmers in zone 2, 7 and 8 are satisfied on the supply of irrigation water to their respective fields (for more details see Table D-8).

***7) Low flow ratio;*** Flow ratio is low because it has no weekly plan for water delivery. RID staffs operate the irrigation water gates based on their own experiences rather than complying with some scientific rules. Farmers do not receive adequacy of irrigation water to their areas.

**Impact (I)**

There are several conditions that may severely threaten the sustainability of irrigation system. These are observed in PPP as shown below:

***1) Poor water quality****;* After farmers divert water to their plots for growing crops, they drain excess water from their fields to the drainage system and water is extracted to the drainage way which is contaminated with fertilizer, weedicide and pesticide. This causes problems of water quality from agriculture.

***2) Low net farm income*;** The low value of the net farm income is due to high production costs, low crop yield and low selling price of crop. The production costs involve the total costs of seeds, fertilizers, pesticides, land preparation, land renting, seeding, harvesting and transportation, etc. Crop yield is low due to low flow ratio. Selling price depends on the moisture content of rice and the presence of rice mills which are located at different places in this project. These cause the net farm income to be low.

***3) Increase conflict among farmers;*** The upstream farmers divert irrigation water to their plots or waste any amount of irrigation water without regard to time and the amount diverted and also without following the rules and regulations. However, there is no rule or regulation to punish the farmers who break these agreements. Moreover, the RID staffs operate the irrigation water gates based on their own experiences rather than complying with some scientific rules. Thus the amount of water delivery is not adequate. Farmers do not receive equal share of irrigation water to their fields. This situation creates conflict among farmers.

**Responses (R)**

The study suggests a suitable guidance and implementation for the irrigation sustainability management, for improving and raising the perception on drained water quality, adequacy of water distribution, farm income and flow ratio in PPP and the guidelines are also taking into account the economic, technical environmental and social aspects. According to Palayasoot (2007), practice of water management of an irrigation system can be categorized into three levels of response i.e. on farm level, project level and water source level. The following guidelines are recommended.

**a) On farm level**

In PPP, it is separated into 11 irrigated areas (zones). Each zone will organize the water user groups in each service unit and water user sub-groups have been established according to the ditch sector within the service unit. Each water user group selects its own ditch leader who acts as irrigator and contacts farmer. Zoneman is responsible to water delivery and surveying about crop yield and crop area. Gate tender is responsible of structure e.g. headwork, cross-regulator or regulator. The responses at field level are explained as follows.

1) Establishment and strengthening of water user groups include clear definition of their role in the irrigation water supply and development working relationship, responsibility and management of water user groups on lateral and sub-lateral canal. For example; sewage cleaning, repair, grass cutting and cost sharing.

2) Provision of support services and promotion of mutual assistance;

a. Provision of support services such as agricultural credit, market information, agricultural extension of support service and agricultural inputs.

b. Promoting mutual assistance and pooling of equipment such as rice transplanter, power tiller, pump etc. during land preparation, transplanting and harvest time to reduce production cost.

3) Establishment of rules and regulations are necessary to clearly define water right and motivate the responsibility of farmer on irrigation water use. Enforcement of mechanisms must be introduced to ensure efficiency and address water use.

**b) Project level**

There are O&M staffs and organizations existing in RID to take care of the irrigation facilities. The project engineer will be responsible for the overall project water management. The water master is responsible for the water management in the sub-divided main canals and instruction to the zoneman. The continuous flow system in the main canal and lateral canal are normal water management. The following guidelines are recommended.

1) Promotion of organic fertilizer and decrease using excessive chemical farm inputs to preserve water quality. Providing knowledge on the proper use of agricultural chemicals and hazards arising from careless use. Integrated Pest Management (IPM) is an effective and environmentally sensitive approach to pest management that relies on a combination of common-sense practices in order to protect the environment and ensure the safety of farmers from the hazardous use of pesticide.

2) Monitoring drainage water quality and effluent discharges from critical pollution sources and distributing the information to relevant agencies and the public.

3) Education and training of farmers on crop water requirement (when and how much water to supply), efficient water use and water saving.

4) Teaching economic or financial management is necessary to make farmers understand about cost balancing. Profitability analysis program is a procedure for diagnosing a farm profitability problem (for more details see Chapter 2). Encourage the farmers to keep a record of the farm account such as their input use, expenditure, yield and income and this record that will give information needed to determine the best combination of various enterprises and the proper use of farm credit.

5) Training RID staffs to improve their performance on determination of crop water requirement and water delivery activity for instance. The incentives could be monetary or certificate to a deserving staff such as annual prize for the best plan, and implementation performance.

6) Improvement of irrigation water delivery plan using rotation method during the dry season. To increase adequacy of water distribution among tertiary canals, zoneman should make the irrigation schedule to provide amount of water at the right.

7) Improvement of flow measurement is necessary by adding flow measurement devices to monitor water flow and provide appropriate equipment and technology to monitor and control water delivery efficiently. Calibration or check the functionality of structure to assess its efficiency (e.g. calibration of flow at main the regulator and intake gate).

**c) Water source level (RIO and RID)**

Regional Irrigation Office 12 (RIO) and RID are responsible for water allocation among the irrigation projects which share common water source and pay much attention in restructuring both the administration aspect and irrigation management.

1) Legislation of agricultural wastewater law or act to control wastewater from agriculture practices and define the effluent standard. This law will reinforce the protection of water from pollution.

2) Collection of irrigation water fee is necessary to cover for maintenance expense and future rehabilitation and to improve water use efficiency. Based on the survey, in PPP, farmers have willingness to pay for irrigation water fee at a medium to height level, average rate of 20 Baht/rai/year (see Table D-8).

3) Provision of external support for major rehabilitation of infrastructure, human and social development, natural resources and environment, economic development, water resource development and administration.

DPSIR framework is useful in describing the links among the indicators influencing sustainability of irrigation system, status and impacts of problem and then provides a basis in formulating management options for improving irrigation sustainability. The common management options to both projects are establishment and strengthening of water user groups, provision of support and promotion of mutual help, establishment of rules and regulations on water use and collection of irrigation water fee. The specific management option to KPP is improvement of water distribution schedule. Legislation of agricultural wastewater law and improvement of water delivery plan on the other hand, are the specific management options to PPP.

# Chapter 5
# Conclusions and Recommendations

## 5.1 Conclusions

This study focused on the development of irrigation sustainability index (ISI) for two irrigation projects in Tha Chin Basin, Thailand namely: Kamphaengsaen O&M Project (KPP) and Phophraya O&M Project (PPP). The assessment of the two projects is based on the investigation of sustainability indicators according to four major groups (i.e. physical, socio-economic, institutional and environmental indicators). These indicators are analyzed using principal component analysis (PCA), whereby dominant indicators influencing irrigation sustainability are identified. Afterwards, the indicators are weighted and computed to obtain an irrigation sustainability index (ISI). The index is used to classify the sustainability of each irrigated area (zone) into five levels. Using geographic information system (GIS) technique, the ISI map is created to provide a better visualization of the areas that have different levels of irrigation sustainability. The results for KPP show that net farm income, awareness on irrigation water use, matching of farm operations with RID water delivery, and field application ratio are the main sustainability indicators. Among the 27 zones in KPP, six zones show very low sustainability level; five zones are low, 11 zones are medium, four zones are high and one zone is very high. Four key indicators are found in PPP, which include perception of drained water quality, satisfaction on adequacy of water distribution, flow ratio, and net farm income. Among the 11 zones in PPP, there are four zones that show very low sustainability level; one zone is low, four zones are medium, one zone is high and another one zone is very high.

The only one common indicator to both systems is net farm income. The specific indicators for KPP are awareness on irrigation water use, matching of farm operations with RID water delivery, and field application ratio. Perception of drained water quality, satisfaction on adequacy of water distribution and flow ratio on the other hand, are the specific indicators for PPP. This can be explained by the fact that KPP shows a diversity of crops such as rice, sugarcane, vegetable and fruit, while rice is the main crop in PPP. Also cropping pattern of rice is different: KPP is double-cropped while PPP is cultivated five times every two year. For the irrigation deliveries, KPP and PPP have pre-season plans, but unlike KPP, PPP has no weekly plan. Furthermore, farmers in KPP use irrigation water whereas some farmers in PPP use drainage water.

Based on the results of the study, it shows that each zone or project can be vulnerable to different causal factors influencing sustainability of irrigation system so there is a need to improve the sustainability of some zones in the two projects. So this study adopts a modified DPSIR framework to describe the links among the indicators influencing sustainability of irrigation system, status and impacts of problem and to formulate management options. The common management options to both projects are establishment and strengthening of water user groups, provision of support and promotion of mutual help, establishment of rules and regulations on water use, collection of irrigation water fee and education and training of farmers. The specific management option for KPP is improvement of water distribution schedule. On the other hand, legislation of agricultural wastewater law and improvement of water delivery plan are the specific management options for PPP.

Based on the identification of factors affecting irrigation system, the assessment of irrigation sustainability and the use of DPSIR framework, the results of the study provided valuable information that could help or give direction in the formulation of policies or suitable guidelines for irrigation management based on economic, technical, environmental and social features and would eventually benefit the farmers in the project areas. The research findings are also compared with field surveys, discussion with officials and interview of farmers, and results show that the key indicators identified in this study closely matched fields' observations. For example, matching of farm operations with RID water delivery is not good which can be explained by the fact that farmers' satisfaction on RID water allocation is low because gate operation is mainly for rice and sugarcane irrigation. However, there are many other crops grown in KPP (e.g. asparagus, vegetable and baby corn) which are not adequately irrigated because their cropping schedules do not match delivery plan. On the other hand, low flow ratio is found from analysis in PPP which can be explained by the fact that this project does not have weekly plan for water delivery that is why zonemen operate gate based only on their experiences and water master instructions.

The above findings confirm that the methodology developed in this study could be adopted and tested for identification of key indicators influencing sustainability of irrigation system and for evaluating and improving irrigation sustainability of other irrigated areas in Thailand.

## 5.2 Recommendations

PCA is useful for reducing many variables to only those which are suitable and highly correlated. The variables should be quantitative at the interval and ratio scale. In this study, some variables (i.e. flooding frequency and crop residue treatment method) which contribute to sustainability are excluded because of limitation of PCA. These variables are categorical data which are not suitable for PCA. Thus, further analysis should be done to prepare and convert data into ordinal or ratio scale.

This study required a large data set to cover four categories of factors i.e. physical, socio-economic, institutional and environmental. Water sampling, soil sampling and soil analysis and socio-economic survey were the most costly and time consuming. However, the procedure to determine ISI can be simplified by using available data for example available soil map can be used for soil characteristics data (e.g. chemical properties of soil), RID survey data and the secondary data (e.g. flow, land use map, climatic data) can be used for identifying irrigation sustainability indicator in the irrigation project. Further study should be undertaken to include other parameters e.g. crop productivity, drained water quality at drainage system, field application systems, groundwater and soil sodicity which affect the soil environment.

ISI can identify which particular zones of an irrigation system and facing management issues based on key indicators. For example, In KPP, the net farm income in zone 1 and 2 is low. Awareness of irrigation water use in zone 1, 2 and 3 is low, matching of farm operations with RID water delivery in zone 2, 3, 13, 14, 22, 26 and 27 is low and field application ratio of zone 21, 23 and 26 is low. Then provide suitable guidelines for irrigation management to minimize these problems (e.g. promotion of mutual help and pooling of equipment, use manual labor instead of machine, establishment of rules and regulations on water use, establishment and strengthening of water user groups and improvement of water distribution schedule, etc). In PPP, farmers in zone 4, 6, 7 and 8 are moderately aware of drained water quality from their field, farmers in zone 1, 3, 4, 5, 6, 9, 10 and 11 are moderately satisfied on the adequacy of water distribution, the net farm income in zone 1, 4, 6, 7 and 8 are low and flow ratio in zone 1, 6, 7 are low. The suitable guidelines for PPP are given (e.g. promotion of organic fertilizer and decrease using excessive chemical farm inputs, establishment of rules and regulations on water use, promotion of mutual assistance and pooling of equipment and improvement of water delivery plan, etc). The above findings have demonstrated that indicators influencing sustainability varied from zone to zone or from one project to another and can be used as basis for further research.

Despite the fact that soil fertility and irrigation water quality are good and irrigation infrastructures in the two projects are available, it is still necessary to maintain soil and water quality and to further improve irrigation management in the two project areas which could include strengthening farmer organization and water user cooperative, etc.

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**Appendixes**

# Appendix A: Water Quality and Climatic Data

Table A-1 Irrigation Water Quality in KPP (Wet Season)

| Sta. | Canal | (pH) | T (water) °C | EC µmhos/cm | TDS (mg/l) | DO (mg/l) |
|---|---|---|---|---|---|---|
| 1 | 3L | 7.39 | 28.30 | 230.50 | 116.00 | 6.75 |
| 2 | 3L | 7.20 | 28.50 | 225.00 | 112.65 | 7.20 |
| 3 | 4L | 7.59 | 28.45 | 227.50 | 114.35 | 6.73 |
| 4 | 4L | 7.13 | 28.35 | 225.00 | 109.30 | 6.88 |
| 5 | 4L | 7.50 | 28.40 | 230.50 | 110.60 | 6.58 |
| 6 | 1L - 4L | 7.29 | 28.30 | 227.00 | 110.20 | 6.49 |
| 7 | 1L - 4L | 7.50 | 28.35 | 228.50 | 112.30 | 6.97 |
| 8 | 1L - 5L | 7.27 | 28.35 | 230.00 | 110.25 | 6.84 |
| 9 | 1L - 5L | 7.24 | 28.40 | 225.50 | 108.15 | 6.85 |
| 10 | 1L - 5L | 7.29 | 28.40 | 224.50 | 110.60 | 6.84 |
| 11 | 2R - 1L - 5L | 7.37 | 28.40 | 227.00 | 109.10 | 6.68 |
| 12 | 1R - 1L - 5L | 7.04 | 28.45 | 228.00 | 109.00 | 6.99 |
| 13 | 1R - 1L - 5L | 6.83 | 28.95 | 224.50 | 107.55 | 7.20 |
| 14 | 1R - 1L - 5L | 6.84 | 29.35 | 223.00 | 106.80 | 7.23 |
| 15 | 1R - 1L - 5L | 6.76 | 29.25 | 220.00 | 106.70 | 7.49 |
| 16 | 1R - 1L - 5L | 6.73 | 29.50 | 222.50 | 106.85 | 7.15 |
| 17 | 1R - 1L - 5L | 6.70 | 29.40 | 224.00 | 107.40 | 7.21 |
| 18 | 1R - 1L - 5L | 6.74 | 28.95 | 222.50 | 108.85 | 7.27 |
| 19 | 1R - 1L - 5L | 6.83 | 28.85 | 221.00 | 108.35 | 7.29 |
| 20 | 1R - 1R - 1L - 5L | 6.55 | 28.95 | 219.00 | 106.50 | 7.64 |
| 21 | 2L - 1R - 1L - 5L | 6.95 | 28.85 | 225.00 | 109.20 | 7.21 |
| 22 | 1L - 1R - 1R - 1L - 5L | 6.62 | 28.65 | 224.00 | 106.55 | 7.13 |
| 23 | 3L - 1R - 1L - 5L | 6.89 | 28.75 | 233.00 | 111.65 | 7.16 |
| 24 | 4L - 1R - 1L - 5L | 7.37 | 28.85 | 220.50 | 107.75 | 7.09 |
| 25 | 5L - 1R - 1L - 5L | 7.07 | 28.72 | 221.00 | 107.10 | 7.08 |
| 26 | 6L - 1R - 1L - 5L | 7.18 | 28.72 | 227.00 | 110.35 | 7.50 |
| 27 | 7L - 1R - 1L - 5L | 7.32 | 28.80 | 231.00 | 111.20 | 7.31 |
| 28 | 8L - 1R - 1L - 5L | 7.41 | 28.80 | 254.50 | 107.40 | 6.83 |
| 29 | 2R - 1R - 1L - 5L | 7.00 | 28.90 | 226.50 | 107.35 | 7.09 |
| 30 | 2R - 1R - 1L - 5L | 7.22 | 29.00 | 227.00 | 110.50 | 7.27 |
| 31 | 2R - 1R - 1L - 5L | 7.04 | 28.75 | 232.00 | 111.40 | 7.29 |
| 32 | 1L - 2R - 1R - 1L - 5L | 7.00 | 28.75 | 244.50 | 109.90 | 7.33 |
| 33 | 3R - 2R - 1R - 1L - 5L | 7.15 | 28.95 | 222.00 | 112.05 | 7.04 |
| 34 | 4R - 2R - 1L - 1L - 5L | 7.01 | 28.75 | 224.00 | 109.35 | 7.08 |
| 35 | 4R - 2R - 1L - 1L - 5L | 6.89 | 28.80 | 232.00 | 109.90 | 7.16 |
| 36 | 1L - 2R - 1R - 1L - 5L | 6.79 | 28.80 | 232.50 | 109.20 | 7.04 |
| 37 | 5R - 2R - 1R - 1L - 5L | 7.55 | 28.55 | 221.50 | 112.70 | 7.66 |
| 38 | 2L - 5L | 7.24 | 28.55 | 223.00 | 109.30 | 7.48 |
| 39 | 2L - 5L | 7.20 | 29.03 | 222.00 | 114.35 | 7.46 |
| 40 | 2L - 5L | 7.17 | 28.90 | 222.50 | 115.55 | 7.42 |
| 41 | 2L - 5L | 7.23 | 29.05 | 224.50 | 113.40 | 7.23 |
| 42 | 2L - 5L | 7.18 | 28.91 | 230.00 | 114.95 | 7.38 |
| 43 | 1L - 2L - 5L | 7.16 | 29.25 | 242.50 | 116.90 | 7.00 |
| 44 | 1L - 2L - 5L | 7.22 | 29.45 | 237.50 | 118.30 | 6.73 |

Table A-2 Irrigation Water Quality in KPP (Dry Season)

| Sta. | Canal | pH | T (water) °C | EC µmhos/cm | TDS (mg/l) | DO (mg/l) |
|---|---|---|---|---|---|---|
| 1 | 3L | 7.64 | 30.00 | 193.20 | 92.45 | 6.79 |
| 2 | 3L | 8.14 | 29.95 | 222.50 | 92.05 | 7.52 |
| 3 | 4L | 7.79 | 29.95 | 191.65 | 92.05 | 7.06 |
| 4 | 4L | 8.17 | 30.10 | 192.85 | 92.20 | 7.88 |
| 5 | 4L | 8.04 | 30.30 | 194.10 | 91.05 | 7.95 |
| 6 | 1L - 4L | 7.76 | 30.20 | 193.90 | 91.50 | 8.94 |
| 7 | 1L - 4L | 7.95 | 30.25 | 193.00 | 92.60 | 7.07 |
| 8 | 1L - 5L | 7.66 | 30.50 | 196.25 | 93.65 | 8.01 |
| 9 | 1L - 5L | 7.97 | 30.40 | 191.65 | 92.35 | 8.16 |
| 10 | 1L - 5L | 8.03 | 30.75 | 204.00 | 96.50 | 5.72 |
| 11 | 2R - 1L - 5L | 8.13 | 31.30 | 196.10 | 94.90 | 7.77 |
| 12 | 1R - 1L - 5L | 7.90 | 30.30 | 192.85 | 94.90 | 7.17 |
| 13 | 1R - 1L - 5L | 7.91 | 30.30 | 192.15 | 92.90 | 7.34 |
| 14 | 1R - 1L - 5L | 7.84 | 30.70 | 191.05 | 91.30 | 8.02 |
| 15 | 1R - 1L - 5L | 7.78 | 30.40 | 188.35 | 89.55 | 7.71 |
| 16 | 1R - 1L - 5L | 7.89 | 30.50 | 188.00 | 85.90 | 8.19 |
| 17 | 1R - 1L - 5L | 7.98 | 30.80 | 189.00 | 90.95 | 7.63 |
| 18 | 1R - 1L - 5L | 8.02 | 31.05 | 191.20 | 91.70 | 7.73 |
| 19 | 1R - 1L - 5L | 8.04 | 31.20 | 193.20 | 91.70 | 7.06 |
| 20 | 1R - 1R - 1L - 5L | 8.19 | 31.70 | 190.60 | 90.25 | 7.95 |
| 21 | 2L - 1R - 1L - 5L | 8.33 | 29.35 | 221.05 | 100.85 | 7.33 |
| 22 | 1L - 1R - 1R - 1L - 5L | 8.17 | 31.35 | 189.35 | 88.95 | 7.59 |
| 23 | 3L - 1R - 1L - 5L | 8.18 | 30.05 | 188.25 | 89.10 | 7.34 |
| 24 | 4L - 1R - 1L - 5L | 8.04 | 30.10 | 188.25 | 90.60 | 7.32 |
| 25 | 5L - 1R - 1L - 5L | 8.16 | 29.80 | 184.40 | 95.80 | 7.63 |
| 26 | 6L - 1R - 1L - 5L | 7.99 | 30.15 | 182.40 | 91.60 | 7.61 |
| 27 | 7L - 1R - 1L - 5L | 7.62 | 31.15 | 227.60 | 110.90 | 7.37 |
| 28 | 8L - 1R - 1L - 5L | 7.99 | 30.90 | 192.30 | 89.80 | 6.93 |
| 29 | 2R - 1R - 1L - 5L | 6.95 | 29.20 | 186.10 | 86.30 | 8.07 |
| 30 | 2R - 1R - 1L - 5L | 7.08 | 29.45 | 182.35 | 87.45 | 8.18 |
| 31 | 2R - 1R - 1L - 5L | 7.11 | 30.05 | 191.90 | 90.70 | 7.71 |
| 32 | 1L - 2R - 1R - 1L - 5L | 7.42 | 28.95 | 175.80 | 86.50 | 7.07 |
| 33 | 3R - 2R - 1R - 1L - 5L | 6.43 | 29.35 | 183.80 | 88.80 | 7.40 |
| 34 | 4R - 2R - 1L - 1L - 5L | 7.07 | 29.60 | 179.10 | 87.25 | 7.24 |
| 35 | 4R - 2R - 1L - 1L - 5L | 7.07 | 30.30 | 192.85 | 92.75 | 7.30 |
| 36 | 1L - 2R - 1R - 1L - 5L | 8.34 | 32.50 | 178.45 | 85.75 | 7.31 |
| 37 | 5R - 2R - 1R - 1L - 5L | 7.48 | 30.50 | 195.30 | 93.60 | 7.95 |
| 38 | 2L - 5L | 7.26 | 29.90 | 187.35 | 87.30 | 7.58 |
| 39 | 2L - 5L | 7.09 | 30.40 | 182.00 | 88.20 | 7.64 |
| 40 | 2L - 5L | 6.88 | 30.35 | 180.20 | 85.90 | 7.39 |
| 41 | 2L - 5L | 6.94 | 30.10 | 188.20 | 90.65 | 7.23 |
| 42 | 2L - 5L | 6.72 | 29.95 | 322.00 | 100.85 | 7.58 |
| 43 | 1L - 2L - 5L | 6.76 | 30.10 | 180.10 | 83.60 | 7.26 |
| 44 | 1L - 2L - 5L | 7.30 | 31.10 | 198.90 | 98.60 | 6.70 |

## Table A-3 Irrigation Water Quality in PPP (Wet season)

| Sta. | Canal | Parameter of irrigation water quality | | | | |
|---|---|---|---|---|---|---|
| | | pH | T (water) °C | EC μmhos/cm | TDS (mg/l) | DO (mg/l) |
| 1 | 2L-1L | 6.87 | 30.05 | 218.35 | 109.00 | 3.28 |
| 2 | 2L-1L | 6.99 | 29.45 | 2209.00 | 1115.00 | 4.05 |
| 3 | 1L | 6.86 | 30.20 | 213.50 | 106.50 | 2.66 |
| 4 | 1L | 6.99 | 30.50 | 230.05 | 115.00 | 4.33 |
| 5 | 1L | 6.77 | 30.10 | 223.55 | 112.00 | 3.01 |
| 6 | 3L-1L | 6.85 | 30.25 | 223.25 | 111.50 | 3.29 |
| 7 | 3L-1L | 6.94 | 29.75 | 234.25 | 117.00 | 3.59 |
| 8 | 3L-1L | 7.17 | 29.90 | 243.50 | 121.50 | 4.24 |
| 9 | 1L-1L | 6.98 | 29.95 | 218.30 | 109.00 | 3.83 |
| 10 | 1L-1L | 6.92 | 29.60 | 221.80 | 110.50 | 3.04 |
| 11 | 1L-1L | 6.82 | 29.75 | 227.50 | 113.50 | 3.12 |
| 12 | 1L-1L | 6.88 | 29.80 | 278.95 | 140.00 | 2.73 |
| 13 | 1R-1L-1L | 6.89 | 29.85 | 217.20 | 108.50 | 2.98 |
| 14 | 1R-1L-1L | 7.19 | 29.55 | 241.35 | 120.50 | 4.61 |
| 15 | 1R-1L-1L | 6.95 | 29.75 | 237.00 | 118.50 | 3.43 |
| 16 | 1R-1L | 6.88 | 30.10 | 227.55 | 114.00 | 3.40 |
| 17 | 1R-1L | 7.05 | 30.40 | 227.65 | 114.00 | 3.87 |
| 18 | 1R-1L | 6.82 | 30.40 | 238.80 | 119.00 | 1.95 |
| 19 | Drain Suphan 3-5R | 6.89 | 29.10 | 266.00 | 133.00 | 1.25 |
| 20 | Drain Suphan 4 | 7.03 | 29.85 | 278.40 | 139.00 | 2.37 |
| 21 | Drain Suphan 4 | 6.95 | 29.90 | 282.30 | 141.00 | 2.20 |
| 22 | Bangplama Regulator | 6.94 | 30.00 | 260.80 | 130.50 | 1.55 |

## Table A-4 Irrigation Water Quality in PPP (Dry season)

| Sta. | Canal | Parameter of irrigation water quality | | | | |
|---|---|---|---|---|---|---|
| | | pH | T (water) °C | EC μmhos/cm | TDS (mg/l) | DO (mg/l) |
| 1 | 2L-1L | 7.57 | 31.05 | 219.90 | 110.00 | 5.18 |
| 2 | 2L-1L | 7.51 | 31.10 | 257.40 | 128.50 | 2.71 |
| 3 | 1L | 7.64 | 31.15 | 227.10 | 114.00 | 2.74 |
| 4 | 1L | 7.15 | 29.30 | 222.00 | 111.00 | 5.16 |
| 5 | 1L | 7.17 | 31.10 | 224.55 | 112.50 | 2.71 |
| 6 | 3L-1L | 7.27 | 32.05 | 221.80 | 111.00 | 3.58 |
| 7 | 3L-1L | 7.28 | 31.35 | 233.85 | 117.50 | 3.45 |
| 8 | 3L-1L | 7.29 | 31.00 | 247.40 | 124.00 | 3.85 |
| 9 | 1L-1L | 7.38 | 31.35 | 222.80 | 113.00 | 3.59 |
| 10 | 1L-1L | 7.23 | 31.40 | 225.50 | 112.50 | 4.04 |
| 11 | 1L-1L | 7.05 | 31.70 | 294.40 | 147.00 | 3.44 |
| 12 | 1L-1L | 7.19 | 32.05 | 293.05 | 146.50 | 4.12 |
| 13 | 1R-1L-1L | 6.63 | 31.30 | 224.10 | 112.00 | 3.01 |
| 14 | 1R-1L-1L | 7.21 | 31.80 | 230.10 | 115.50 | 5.05 |
| 15 | 1R-1L-1L | 7.39 | 32.05 | 226.81 | 113.50 | 4.97 |
| 16 | 1R-1L | 7.12 | 30.95 | 218.75 | 109.50 | 2.72 |
| 17 | 1R-1L | 7.20 | 31.45 | 226.70 | 113.50 | 4.15 |
| 18 | 1R-1L | 6.85 | 31.10 | 229.15 | 115.00 | 2.33 |
| 19 | Drain Suphan 3-5R | 7.03 | 30.65 | 297.50 | 149.50 | 1.30 |
| 20 | Drain Suphan 4 | 7.08 | 30.65 | 299.00 | 149.50 | 2.46 |
| 21 | Drain Suphan 4 | 7.08 | 30.45 | 286.80 | 143.50 | 2.03 |
| 22 | Bangplama Regulator | 6.92 | 30.10 | 259.40 | 129.50 | 0.74 |

Table A-5 Standard of Irrigation Water Quality for Agriculture

| No. | Parameter | Value |
|---|---|---|
| 1 | pH | 6.5-8.5 |
| 2 | EC | ≤700 mhos/cm |
| 3 | Ca | ≤ 40 ppm |
| 4 | Mg | ≤ 20 ppm |
| 5 | Na | ≤ 10 ppm |
| 6 | K | NA |
| 7 | $CO_3$ | ≤ 10 ppm |
| 8 | $HCO_3$ | ≤ 480 ppm |
| 9 | Cl | ≤ 750 ppm |
| 10 | $SO_4$ | ≤ 400 ppm |
| 11 | Adj-RNA | ≤ 3 ppm |
| 12 | SAR | ≤ 4 ppm |
| 13 | SSP | ≤ 60 % |
| 14 | RSC | ≤ 2.5 meq/l |
| 15 | TDS | ≤ 500 ppm |
| 16 | Ca | NA |
| 17 | Turbidity | ≤ 40 NTU |
| 18 | Mn | ≤0.5 ppm |
| 19 | Fe | ≤1 ppm |
| 20 | D, Fe | ≤ 0.5 ppm |
| 21 | TH | ≤ 500 ppm |
| 22 | NCH | ≤ 300 ppm |
| 23 | $NO_3$ | ≤ 400 ppm |

Source: (RID, 2007e)

Table A-6 Value of Parameters of Soil in KPP

| Zone | pH (1:1) | EC (1:5,dS/m) | OM (%) | N (%) | P (mg kg-1) | K (mg kg-1) | Ca (mg kg-1) | Mg (mg kg-1) | CEC (Cmol/kg) | BS (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 6.54 | 0.09 | 2.40 | 0.12 | 11.50 | 68.50 | 3318.00 | 299.50 | 22.03 | 97.55 |
| 2 | 6.68 | 0.13 | 2.36 | 0.12 | 11.00 | 95.00 | 2863.67 | 235.33 | 17.29 | 93.52 |
| 3 | 6.76 | 0.14 | 1.69 | 0.09 | 21.33 | 106.33 | 3516.67 | 308.67 | 18.20 | 99.51 |
| 4 | 6.01 | 0.16 | 2.33 | 0.12 | 34.94 | 206.25 | 2439.06 | 249.81 | 16.98 | 89.33 |
| 5 | 5.72 | 0.09 | 2.45 | 0.13 | 27.50 | 157.50 | 2052.25 | 238.00 | 15.47 | 86.36 |
| 6 | 5.54 | 0.28 | 2.31 | 0.12 | 54.00 | 122.67 | 3163.33 | 252.67 | 16.20 | 100.00 |
| 7 | 6.21 | 0.09 | 2.95 | 0.12 | 137.67 | 184.00 | 3095.33 | 251.33 | 18.66 | 100.00 |
| 8 | 6.65 | 0.19 | 2.12 | 0.10 | 38.67 | 143.00 | 2893.00 | 318.67 | 17.57 | 100.00 |
| 9 | 6.78 | 0.23 | 2.34 | 0.12 | 100.00 | 208.00 | 2238.00 | 246.33 | 15.74 | 96.70 |
| 10 | 6.59 | 0.42 | 1.73 | 0.09 | 238.33 | 178.00 | 2453.00 | 448.67 | 16.75 | 100.00 |
| 11 | 6.71 | 0.42 | 2.42 | 0.12 | 180.67 | 164.00 | 4236.33 | 696.33 | 16.75 | 100.00 |
| 12 | 6.64 | 0.29 | 1.77 | 0.09 | 192.25 | 171.00 | 4576.50 | 427.25 | 13.01 | 100.00 |
| 13 | 6.17 | 0.44 | 3.24 | 0.17 | 11.50 | 159.00 | 3482.50 | 668.00 | 18.57 | 94.18 |
| 14 | 5.92 | 0.44 | 1.96 | 0.10 | 36.50 | 117.92 | 4429.42 | 602.33 | 10.96 | 95.99 |
| 15 | 5.77 | 0.49 | 2.10 | 0.10 | 33.78 | 119.76 | 4389.54 | 568.63 | 21.30 | 91.50 |
| 16 | 6.10 | 0.31 | 1.63 | 0.08 | 68.50 | 100.50 | 2159.50 | 392.00 | 15.11 | 98.61 |
| 17 | 4.70 | 0.99 | 3.75 | 0.19 | 17.00 | 234.00 | 2592.00 | 879.50 | 24.58 | 84.70 |
| 18 | 6.08 | 0.36 | 1.74 | 0.09 | 34.00 | 79.67 | 1665.33 | 266.33 | 12.83 | 100.00 |
| 19 | 6.16 | 0.33 | 2.70 | 0.14 | 75.67 | 99.33 | 1992.00 | 406.00 | 12.37 | 100.00 |
| 20 | 6.47 | 0.74 | 2.91 | 0.15 | 15.00 | 180.00 | 2254.00 | 738.50 | 20.30 | 93.79 |
| 21 | 5.83 | 0.80 | 3.09 | 0.16 | 8.50 | 180.00 | 3121.50 | 854.00 | 21.76 | 100.00 |
| 22 | 6.40 | 0.38 | 3.53 | 0.18 | 22.50 | 91.00 | 2349.00 | 720.00 | 22.12 | 100.00 |
| 23 | 6.23 | 0.27 | 2.81 | 0.14 | 11.00 | 162.00 | 1964.00 | 670.50 | 24.58 | 85.52 |
| 24 | 6.13 | 0.46 | 1.92 | 0.10 | 28.50 | 147.00 | 4981.50 | 841.50 | 20.97 | 100.00 |
| 25 | 6.10 | 0.43 | 2.80 | 0.14 | 20.50 | 285.00 | 4500.00 | 1237.50 | 29.86 | 91.36 |
| 26 | 5.73 | 0.83 | 2.52 | 0.13 | 27.00 | 282.00 | 6175.50 | 1266.50 | 31.23 | 92.44 |
| 27 | 5.80 | 0.73 | 2.55 | 0.13 | 23.33 | 174.00 | 3339.67 | 1059.33 | 25.95 | 99.88 |

Table A-7 Value of Parameters of Soil in PPP

| Zone | pH (1:1) | EC (1:5,dS/m) | OM (%) | N (%) | P (mg kg-1) | K (mg kg-1) | Ca (mg kg-1) | Mg (mg kg-1) | CEC (Cmol/kg) | BS (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5.35 | 0.18 | 3.13 | 0.16 | 46.25 | 138.50 | 4884.00 | 534.00 | 25.76 | 84.94 |
| 2 | 5.50 | 0.50 | 3.94 | 0.20 | 80.33 | 122.67 | 3876.00 | 468.67 | 21.66 | 91.60 |
| 3 | 5.18 | 0.35 | 3.33 | 0.17 | 25.25 | 66.75 | 3733.50 | 465.25 | 29.77 | 88.51 |
| 4 | 5.13 | 0.31 | 3.55 | 0.18 | 44.00 | 144.67 | 3804.33 | 490.67 | 20.12 | 86.88 |
| 5 | 5.05 | 0.33 | 3.98 | 0.20 | 55.75 | 153.00 | 5136.00 | 746.25 | 25.80 | 93.84 |
| 6 | 4.57 | 0.48 | 3.93 | 0.20 | 16.67 | 219.00 | 5734.33 | 809.00 | 28.41 | 84.79 |
| 7 | 5.05 | 0.47 | 5.14 | 0.26 | 100.75 | 180.75 | 6214.50 | 572.25 | 34.33 | 85.41 |
| 8 | 4.85 | 0.24 | 5.18 | 0.26 | 33.75 | 126.25 | 4366.25 | 612.75 | 22.48 | 78.29 |
| 9 | 4.80 | 0.38 | 4.04 | 0.20 | 23.67 | 119.33 | 5994.67 | 680.33 | 31.14 | 92.45 |
| 10 | 4.83 | 0.50 | 4.78 | 0.24 | 32.75 | 211.50 | 5781.00 | 689.50 | 31.14 | 83.91 |
| 11 | 5.17 | 0.58 | 4.01 | 0.20 | 16.33 | 164.00 | 5970.00 | 576.33 | 25.76 | 100.00 |

Table A-8 Average Monthly Rainfall Data at KPP

| Station | Monthly Rainfall, mm (1993-2007) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Dry Season | | | | | | | Wet Season | | | | | | |
| | Jan. | Feb | Mar. | Apr. | May | Jun | Average | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Average |
| Station1 | 2.78 | 5.61 | 29.71 | 46.74 | 136.78 | 106.04 | 54.61 | 95.81 | 114.22 | 215.67 | 173.18 | 31.50 | 6.69 | 106.18 |
| Station2 | 4.96 | 0.95 | 42.33 | 28.71 | 109.87 | 97.73 | 47.73 | 87.30 | 107.53 | 223.87 | 174.88 | 23.42 | 4.97 | 103.66 |
| Station3 | 1.20 | 5.60 | 27.58 | 52.28 | 145.37 | 134.29 | 61.05 | 102.70 | 116.23 | 212.24 | 164.25 | 30.15 | 4.97 | 105.09 |
| Station4 | 2.04 | 2.98 | 23.70 | 45.88 | 153.89 | 118.26 | 57.79 | 101.39 | 105.03 | 232.62 | 194.56 | 33.59 | 8.39 | 112.60 |
| Station5 | 2.99 | 5.69 | 26.27 | 36.07 | 107.47 | 99.44 | 46.32 | 87.31 | 94.19 | 192.21 | 161.93 | 28.14 | 5.43 | 94.87 |
| Station 23012 | 2.58 | 6.66 | 33.90 | 33.35 | 133.57 | 122.07 | 55.36 | 2.58 | 6.66 | 33.90 | 33.35 | 133.57 | 122.07 | 55.36 |
| Station 23022 | 10.78 | 6.45 | 55.02 | 38.68 | 162.86 | 112.54 | 64.39 | 10.78 | 6.45 | 55.02 | 38.68 | 162.86 | 112.54 | 64.39 |
| Station 23042 | 1.83 | 10.26 | 41.27 | 65.82 | 136.19 | 95.65 | 58.50 | 1.83 | 10.26 | 41.27 | 65.82 | 136.19 | 95.65 | 58.50 |
| Station 23062 | 2.94 | 8.26 | 42.67 | 33.71 | 112.67 | 96.42 | 49.45 | 2.94 | 8.26 | 42.67 | 33.71 | 112.67 | 96.42 | 49.45 |
| Station 23202 | 1.99 | 5.60 | 22.48 | 38.00 | 111.95 | 100.52 | 46.76 | 1.99 | 5.60 | 22.48 | 38.00 | 111.95 | 100.52 | 46.76 |

Table A-9 Average Mean Temperature Data at KPP

| Station | Temperature, °C (1993-2007) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Dry Season | | | | | | | Wet Season | | | | | | |
| | Jan. | Feb | Mar. | Apr. | May | Jun | Average | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Average |
| Agromet Pathumthani | 27.20 | 28.40 | 29.70 | 30.76 | 30.03 | 29.73 | 29.30 | 29.49 | 29.25 | 28.96 | 28.78 | 27.67 | 26.41 | 28.43 |
| Agromet Rachaburi | 26.15 | 27.67 | 29.25 | 30.59 | 29.85 | 29.33 | 28.81 | 28.93 | 28.79 | 28.45 | 27.61 | 26.45 | 25.30 | 27.59 |
| Agromet U Thong | 25.12 | 27.01 | 29.37 | 30.74 | 30.09 | 29.72 | 28.68 | 29.20 | 28.97 | 28.47 | 27.68 | 26.32 | 24.44 | 27.51 |
| Agromet Kamphaengsaen | 25.23 | 27.16 | 29.22 | 30.49 | 29.95 | 29.55 | 28.60 | 29.05 | 28.83 | 28.50 | 27.69 | 26.09 | 24.37 | 27.42 |
| Agromet Bang Na | 26.93 | 28.21 | 29.70 | 30.68 | 30.07 | 29.63 | 29.20 | 29.29 | 28.99 | 28.64 | 28.41 | 27.79 | 26.29 | 28.24 |
| Suphanburi | 25.40 | 27.20 | 28.90 | 30.30 | 29.80 | 29.10 | 28.45 | 28.60 | 28.40 | 28.10 | 27.80 | 26.40 | 24.60 | 27.32 |
| Kanchanaburi | 25.60 | 27.90 | 29.90 | 31.10 | 29.90 | 28.90 | 28.88 | 28.50 | 28.20 | 27.90 | 27.20 | 26.10 | 24.70 | 27.10 |
| Bangkok metropolis | 26.40 | 27.70 | 29.10 | 30.10 | 29.70 | 29.10 | 28.68 | 28.70 | 28.40 | 28.00 | 27.80 | 27.10 | 25.90 | 27.65 |
| Don Muang | 26.30 | 27.70 | 28.90 | 29.80 | 29.50 | 28.90 | 28.52 | 28.60 | 28.40 | 28.10 | 27.90 | 27.20 | 25.80 | 27.67 |

Table A-10 Average Relative Humidity Data at KPP

| Station | Relative Humidity, % (1993-2007) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Dry Season | | | | | | | Wet Season | | | | | | |
| | Jan. | Feb | Mar. | Apr. | May | Jun | Average | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Average |
| Agromet Pathumthani | 65.56 | 66.44 | 67.22 | 68.78 | 71.50 | 71.20 | 68.45 | 71.40 | 71.60 | 73.30 | 72.30 | 67.70 | 64.11 | 70.07 |
| Agromet Rachaburi | 65.77 | 64.92 | 66.69 | 67.15 | 71.08 | 72.77 | 68.06 | 73.36 | 74.29 | 77.07 | 78.43 | 73.50 | 68.00 | 74.11 |
| Agromet U Thong | 67.07 | 65.86 | 65.14 | 65.00 | 69.07 | 69.00 | 66.86 | 70.21 | 70.50 | 73.14 | 74.21 | 70.86 | 67.38 | 71.05 |
| Agromet Kamphaengsaen | 69.07 | 67.67 | 68.40 | 68.53 | 72.33 | 73.73 | 69.96 | 74.80 | 75.07 | 76.20 | 76.87 | 73.20 | 70.46 | 74.43 |
| Agromet Bang Na | 66.33 | 67.60 | 70.07 | 69.93 | 71.07 | 71.36 | 69.39 | 72.07 | 71.93 | 72.80 | 71.13 | 69.07 | 67.47 | 70.75 |
| Suphanburi | 70.00 | 71.00 | 71.00 | 70.00 | 73.00 | 73.00 | 71.33 | 75.00 | 76.00 | 80.00 | 80.00 | 75.00 | 70.00 | 76.00 |
| Kanchanaburi | 63.00 | 60.00 | 59.00 | 61.00 | 69.00 | 72.00 | 64.00 | 72.00 | 73.00 | 77.00 | 79.00 | 73.00 | 65.00 | 73.17 |
| Bangkok metropolis | 71.00 | 73.00 | 74.00 | 74.00 | 76.00 | 76.00 | 74.00 | 76.00 | 77.00 | 80.00 | 80.00 | 73.00 | 69.00 | 75.83 |
| Don Muang | 67.00 | 70.00 | 71.00 | 73.00 | 75.00 | 74.00 | 71.67 | 75.00 | 76.00 | 79.00 | 78.00 | 72.00 | 84.00 | 77.33 |

Table A-11 Average Monthly Rainfall Data at PPP

| Station | Monthly Rainfall, mm (1993-2007) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Dry Season | | | | | | | Wet Season | | | | | | |
| | Jan. | Feb | Mar. | Apr. | May | Jun | Average | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Average |
| SUP26 (60270) | 4.19 | 17.57 | 34.36 | 95.65 | 193.42 | 151.23 | 82.74 | 169.71 | 159.36 | 404.43 | 271.29 | 48.76 | 10.88 | 177.41 |
| SUP36 (60300) | 3.83 | 8.30 | 19.55 | 51.30 | 120.43 | 94.38 | 49.63 | 90.04 | 95.24 | 246.58 | 193.53 | 48.91 | 2.45 | 112.79 |
| SUP38 (60320) | 1.23 | 5.65 | 18.65 | 49.28 | 106.78 | 126.24 | 51.30 | 87.89 | 88.39 | 224.64 | 177.72 | 36.75 | 3.75 | 103.19 |
| SUP55 (60470) | 1.73 | 15.36 | 22.98 | 60.84 | 113.48 | 85.93 | 50.05 | 95.63 | 96.54 | 219.73 | 165.83 | 20.86 | 5.63 | 100.70 |
| SUP56 (60410) | 0.00 | 10.15 | 9.72 | 38.61 | 100.49 | 68.11 | 37.85 | 72.19 | 84.57 | 225.72 | 123.71 | 22.39 | 0.68 | 88.21 |
| SUP57 (60420) | 0.00 | 8.64 | 6.43 | 32.90 | 85.61 | 65.09 | 33.11 | 52.73 | 69.69 | 186.98 | 112.99 | 18.36 | 0.57 | 73.55 |
| SUP58 (60480) | 1.33 | 8.77 | 19.13 | 44.92 | 106.11 | 80.49 | 43.46 | 73.42 | 91.55 | 203.48 | 173.67 | 30.81 | 3.29 | 96.04 |
| SUP64 (60500) | 2.14 | 8.12 | 18.57 | 56.21 | 131.66 | 112.01 | 54.78 | 98.93 | 122.54 | 244.28 | 168.13 | 32.42 | 2.75 | 111.51 |
| Patumthani | 3.36 | 25.48 | 74.20 | 122.19 | 195.39 | 170.53 | 98.52 | 152.95 | 154.27 | 251.07 | 152.30 | 43.15 | 6.39 | 126.69 |
| Ayutaya | 6.56 | 6.10 | 39.92 | 63.41 | 141.98 | 127.95 | 64.32 | 120.59 | 160.09 | 241.44 | 108.50 | 37.35 | 11.35 | 113.22 |
| Chainat | 3.59 | 13.01 | 28.36 | 65.23 | 140.78 | 103.74 | 59.12 | 103.17 | 118.69 | 238.63 | 121.14 | 26.05 | 5.21 | 102.15 |
| Supanburi | 4.54 | 9.57 | 30.18 | 70.07 | 131.79 | 98.87 | 57.50 | 93.85 | 104.87 | 247.21 | 164.45 | 40.94 | 5.51 | 109.47 |

Table A-12 Average Mean Temperature Data of PPP

| Station | Temperature , °C (1993-2007) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Dry Season | | | | | | | Wet Season | | | | | | |
| | Jan. | Feb | Mar. | Apr. | May | Jun | Average | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Average |
| Agromet Pathumthani (419301) | 27.20 | 28.40 | 29.70 | 30.76 | 30.03 | 29.73 | 29.30 | 29.49 | 29.25 | 28.96 | 28.78 | 27.67 | 26.41 | 28.43 |
| Ayutaya (415301) | 26.50 | 28.13 | 29.64 | 30.55 | 29.84 | 29.29 | 28.99 | 29.05 | 28.71 | 28.28 | 28.13 | 27.07 | 25.79 | 27.84 |
| Chainat (402301) | 25.95 | 27.54 | 29.39 | 30.61 | 29.93 | 29.55 | 28.83 | 29.07 | 28.73 | 28.53 | 28.26 | 27.09 | 25.41 | 27.85 |
| Suphanburi | 25.4 | 27.2 | 28.9 | 30.3 | 29.8 | 29.1 | 28.45 | 28.6 | 28.4 | 28.1 | 27.8 | 26.4 | 24.6 | 27.32 |

Table A-13 Average Relative Humidity Data of PPP

| Station | Relative Humidity, % (1993-2007) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Dry Season | | | | | | | Wet Season | | | | | | |
| | Jan. | Feb | Mar. | Apr. | May | Jun | Average | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Average |
| Agromet Pathumthani (419301) | 65.56 | 66.44 | 67.22 | 68.78 | 71.50 | 71.20 | 68.45 | 71.40 | 71.60 | 73.30 | 72.30 | 67.70 | 64.11 | 70.07 |
| Ayuttaya (415301) | 62.33 | 63.80 | 66.80 | 69.07 | 72.47 | 73.13 | 67.93 | 72.93 | 74.20 | 76.80 | 73.47 | 68.60 | 62.43 | 71.40 |
| Chainat (402301) | 65.80 | 66.80 | 68.07 | 68.80 | 72.33 | 73.93 | 69.29 | 73.60 | 74.13 | 76.93 | 74.60 | 70.07 | 64.71 | 72.34 |
| Suphanburi | 70 | 71 | 71 | 70 | 73 | 73 | 71.33 | 75 | 76 | 80 | 80 | 75 | 70 | 76.00 |

Table A-14 Parameter of Drained Water in KPP (Wet Season)

| Sta. | Drained Canal | Parameter of Drained Water | | | | |
|---|---|---|---|---|---|---|
| | | (pH) | Temperature °C | EC ( μmhos/cm ) | TDS ( mg/l) | DO ( mg/l ) |
| 1 | Thasan-Bangpla | 5.70 | 26.72 | 475.32 | 280.91 | 2.42 |
| 2 | Thasan-Bangpla | 5.84 | 26.87 | 373.24 | 211.92 | 3.91 |
| 3 | Thasan-Bangpla | 5.64 | 26.89 | 306.43 | 170.81 | 4.38 |
| 4 | D-1R Thasan-Bangpla | 5.88 | 26.80 | 955.82 | 529.86 | 4.57 |
| 5 | D-2R Thasan-Bangpla | 6.04 | 26.89 | 252.55 | 137.11 | 5.52 |
| 6 | D-3R Thasan-Bangpla | 6.29 | 26.83 | 265.24 | 137.57 | 5.14 |
| 7 | D-6R Thasan-Bangpla | 6.00 | 26.79 | 347.76 | 164.69 | 3.36 |
| 8 | D-7R Thasan-Bangpla | 6.01 | 26.79 | 337.43 | 173.37 | 5.81 |
| 9 | D-8R Thasan-Bangpla | 6.48 | 26.84 | 279.10 | 135.94 | 5.02 |
| 10 | D-8R Thasan-Bangpla | 6.38 | 26.10 | 267.37 | 126.84 | 4.44 |
| 11 | D-1R-6R Thasan-Bangpla | 6.31 | 26.85 | 563.46 | 235.67 | 3.86 |
| 12 | D-1R-8R Thasan-Bangpla | 6.14 | 26.11 | 322.73 | 242.71 | 3.32 |
| 13 | D-1L Tharuae-Bangpra | 5.67 | 26.91 | 738.09 | 400.34 | 4.10 |
| 14 | D-1L-1L Tharuae-Bangpra | 5.72 | 26.94 | 603.59 | 464.05 | 2.94 |
| 15 | D-2R-1L Tharuae-Bangpra | 5.74 | 26.93 | 1035.31 | 512.73 | 3.29 |
| 16 | D-4R-1L Tharuae-Bangpra | 5.67 | 26.93 | 765.32 | 422.11 | 3.91 |
| 17 | D-1R-5R-1L Tharuae-Bangpra | 5.99 | 26.90 | 911.27 | 512.79 | 4.67 |
| 18 | D-1R-1R-5R-1L Tharuae-Bangpra | 5.94 | 26.92 | 740.98 | 433.93 | 4.61 |
| 19 | D-2R-5R-1L Tharuae-Bangpra | 5.66 | 27.07 | 785.58 | 452.74 | 3.78 |
| 20 | D-5R-1L Tharuae-Bangpra | 5.72 | 26.96 | 914.69 | 495.21 | 3.91 |
| 21 | Rangyao | 5.75 | 26.99 | 902.84 | 558.54 | 3.69 |
| 22 | Klong-Bangwua | 6.15 | 27.00 | 454.08 | 311.15 | 5.09 |
| 23 | Klong-Namdokmai | 5.51 | 26.98 | 470.37 | 255.50 | 3.58 |
| 24 | Klong_Bangrakum | 6.05 | 26.99 | 456.95 | 318.45 | 5.02 |

Table A-15 Parameter of Drained Water Quality in KPP (Dry Season)

| Sta. | Drained Canal | Parameter of Drained Water | | | | |
|---|---|---|---|---|---|---|
| | | (pH) | Temperature °C | EC ( μmhos/cm ) | TDS ( mg/l) | DO ( mg/l ) |
| 1 | Thasan-Bangpla | 6.86 | 28.33 | 427.54 | 218.20 | 2.57 |
| 2 | Thasan-Bangpla | 6.25 | 28.28 | 346.95 | 285.30 | 3.74 |
| 3 | Thasan-Bangpla | 6.98 | 28.25 | 361.75 | 253.93 | 3.51 |
| 4 | D-1R Thasan-Bangpla | 6.84 | 28.12 | 741.79 | 519.46 | 3.07 |
| 5 | D-2R Thasan-Bangpla | 7.23 | 28.40 | 233.06 | 160.40 | 4.56 |
| 6 | D-3R Thasan-Bangpla | 7.37 | 28.25 | 257.92 | 123.99 | 5.58 |
| 7 | D-6R Thasan-Bangpla | 7.18 | 28.25 | 524.43 | 256.50 | 4.58 |
| 8 | D-7R Thasan-Bangpla | 7.25 | 28.13 | 375.03 | 181.58 | 5.24 |
| 9 | D-8R Thasan-Bangpla | 6.99 | 29.15 | 299.48 | 144.30 | 4.83 |
| 10 | D-8R Thasan-Bangpla | NA | NA | NA | NA | NA |
| 11 | D-1R-6R Thasan-Bangpla | 6.80 | 28.30 | 532.64 | 244.78 | 4.01 |
| 12 | D-1R-8R Thasan-Bangpla | NA | NA | NA | NA | NA |
| 13 | D-1L Tharuae-Bangpra | 7.07 | 28.11 | 397.46 | 310.79 | 3.35 |
| 14 | D-1L-1L Tharuae-Bangpra | 6.86 | 28.59 | 617.34 | 494.95 | 3.48 |
| 15 | D-2R-1L Tharuae-Bangpra | 6.89 | 28.13 | 516.29 | 468.24 | 3.23 |
| 16 | D-4R-1L Tharuae-Bangpra | 6.60 | 28.12 | 813.18 | 441.57 | 3.32 |
| 17 | D-1R-5R-1L Tharuae-Bangpra | 7.37 | 28.11 | 863.57 | 424.14 | 4.99 |
| 18 | D-1R-1R-5R-1L Tharuae-Bangpra | 7.37 | 28.15 | 487.36 | 279.42 | 5.78 |
| 19 | D-2R-5R-1L Tharuae-Bangpra | 6.85 | 28.52 | 659.95 | 343.84 | 4.23 |
| 20 | D-5R-1L Tharuae-Bangpra | 7.08 | 28.13 | 679.24 | 369.70 | 4.14 |
| 21 | Rangyao | 7.19 | 28.28 | 634.14 | 574.47 | 4.43 |
| 22 | Klong-Bangwua | 6.91 | 28.28 | 518.35 | 256.82 | 3.83 |
| 23 | Klong-Namdokmai | 6.96 | 28.31 | 355.06 | 279.10 | 3.94 |
| 24 | Klong_Bangrakum | 7.18 | 28.34 | 681.04 | 438.38 | 4.90 |

Table A-16 Parameter of Drained Water in PPP (Wet Season)

| Sta. | Sampling Location | (pH) | Temperature °C | EC ( µmhos/cm ) | DO ( mg/l ) |
|---|---|---|---|---|---|
| 1 | Saotongthong | 6.85 | 28.97 | 204.21 | 2.65 |
| 2 | Phopraya Gate | 6.75 | 28.96 | 211.36 | 2.53 |
| 3 | Archasimog Bridge | 6.71 | 28.91 | 224.48 | 2.35 |
| 4 | Bangyihon | 6.71 | 28.59 | 243.55 | 2.16 |

Table A-17 Parameter of Drained Water in PPP (Dry Season)

| Sta. | Sampling Location | (pH) | Temperature °C | EC ( µmhos/cm ) | DO ( mg/l ) |
|---|---|---|---|---|---|
| 1 | Saotongthong | 8.17 | 29.53 | 218.80 | 3.43 |
| 2 | Phopraya Gate | 8.41 | 29.54 | 234.60 | 2.62 |
| 3 | Archasimog Bridge | 8.30 | 29.52 | 257.55 | 2.57 |
| 4 | Bangyihon | 7.92 | 29.74 | 284.65 | 2.19 |

Table A-18 Standard of Water Quality for Drained Water

| No. | Parameter | Value |
|---|---|---|
| 1 | pH | 6.5-8.5 |
| 2 | EC | ≤ 2,000 mhos/cm |
| 3 | TDS | ≤1,300 mg/l |
| 4 | T | ≤ 40 °C |
| 5 | DO | ≥ 2mg/l |
| 6 | BOD | ≤ 20mg/l |
| 7 | SS | ≤ 30mg/l |
| 8 | PV | ≤ 60mg/l |
| 9 | $H_2S$ | ≤ 1mg/l |
| 10 | HCN | ≤ 1mg/l |
| 11 | Cl | ≤ 1mg/l |
| 12 | Oil | ≤ 5mg/l |
| 13 | Tar | NA |
| 14 | Zn | ≤ 5 mg/l |
| 15 | Cr | ≤ 0.25 mg/l |
| 16 | As | ≤ 1.0 mg/l |
| 17 | Cu | ≤ 1mg/l |
| 18 | Hg | ≤ 0.005 mg/l |
| 19 | Cd | ≤ 0.03 mg/l |
| 20 | Ba | ≤ 1.0 mg/l |
| 21 | Se | ≤ 0.02mg/l |
| 22 | Pb | ≤ 0.1 mg/l |
| 23 | Ni | ≤ 0.2 mg/l |
| 24 | Mn | ≤ 5 mg/l |

Table A-19 Planned and Delivered Flow on Weekly Plan in KPP (Wet Season)

| Week | Date | Canal 3L | | | Canal 4L | | | Canal 4L(Km.3+100) | | | Canal 1L-4L | | | Canal 1L - 5L | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Planned | Delivered | score | Planned | Delivered | score | Planned | Delivered | score | Planned | Delivered | score | Planned | Delivered | score |
| 4 | 17-23 Jul 2006 | 1 | | | 2.5 | 1.49 | 1 | | | | 0.5 | 0.70 | 5 | 2.5 | 9.99 | 5 |
| 5 | 24-30 Jul 2006 | 1 | 0.52 | 1 | 2 | 2.37 | 5 | | | | 0.5 | 1.46 | 5 | 2.5 | 11.37 | 5 |
| 6 | 31 Jul - 6 Aug 2006 | 1 | 0.60 | 1 | 2.5 | 1.90 | 2 | 1.0 | 0.41 | 1 | 0.5 | 1.34 | 5 | 2.5 | 11.80 | 5 |
| 7 | 7-13 Aug 2006 | 1 | 0.38 | 1 | 2.5 | 1.16 | 1 | 1.0 | 0.58 | 1 | 0.5 | 0.88 | 5 | 2.5 | 11.49 | 5 |
| 8 | 14-20 Aug 2006 | 1 | 0.00 | 1 | 2.5 | 1.13 | 1 | 1.0 | 0.40 | 1 | 0.5 | 0.58 | 5 | 2.5 | 10.85 | 5 |
| 9 | 21-27 Aug 2006 | 1 | 0.00 | 1 | 2.5 | 1.75 | 1 | 1.0 | 0.61 | 1 | 0.5 | 1.06 | 5 | 2.5 | 10.15 | 5 |
| 10 | 28Aug -3Sep2006 | 1 | 0.47 | 1 | 2.5 | 1.58 | 1 | 1.0 | 0.52 | 1 | 0.5 | 0.88 | 5 | 2.5 | 8.70 | 5 |
| 11 | 4-10Sep2006 | 1 | 0.59 | 1 | 2.5 | 1.66 | 1 | 1.0 | 0.55 | 1 | 0.5 | 0.81 | 5 | 3 | 8.39 | 5 |
| 12 | 11-17Sep2006 | 1 | 0.60 | 1 | 2 | 1.47 | 2 | 0.5 | 0.59 | 1 | 0.5 | 0.80 | 5 | 2.5 | 5.29 | 5 |
| 13 | 18-24Sep2006 | 1 | 0.34 | 1 | 2.5 | 1.27 | 1 | 1.0 | 0.50 | 1 | 0.5 | 0.99 | 5 | 4 | 3.73 | 5 |
| 14 | 25Sep-1Oct2006 | 0.5 | 0.28 | 1 | 2.5 | 1.52 | 1 | 1.0 | 0.30 | 1 | 0.5 | 0.84 | 5 | 3 | 6.22 | 5 |
| 15 | 2-8Oct2006 | 1 | 0.52 | 1 | 2.5 | 2.02 | 3 | 1.0 | 0.56 | 1 | 0.5 | 0.89 | 5 | 3 | 6.69 | 5 |
| 16 | 9-15Oct2006 | 1 | 0.53 | 1 | 2.5 | 1.76 | 1 | 1.0 | 0.39 | 1 | 0.5 | 0.89 | 5 | 3 | 6.90 | 5 |
| 17 | 16-22Oct2006 | 1 | 0.54 | 1 | 2.5 | 1.75 | 1 | 1.0 | 0.38 | 1 | 0.5 | 0.87 | 5 | 3 | 6.94 | 5 |
| 18 | 23-29Oct2006 | 1 | 0.60 | 1 | 2.5 | 2.15 | 4 | 1.0 | 0.52 | 1 | 0.5 | 1.17 | 5 | 3 | 8.41 | 5 |
| 19 | 30Oct-5Nov2006 | 1 | 0.57 | 1 | 2.5 | 2.39 | 5 | 1.0 | 0.71 | 1 | 0.5 | 1.40 | 5 | 3 | 9.40 | 5 |
| 20 | 6-12Nov2006 | 1 | 0.59 | 1 | 2.5 | 2.30 | 5 | 1.0 | 0.64 | 1 | 0.5 | 1.58 | 5 | 3 | 8.94 | 5 |
| 21 | 13-19Nov2006 | 1 | 0.51 | 1 | 2.5 | 2.04 | 3 | 1.0 | 0.59 | 1 | 0.5 | 1.38 | 5 | 3 | 8.88 | 5 |
| 22 | 20-26Nov2006 | 1 | 0.50 | 1 | 2.5 | 1.41 | 1 | 1.0 | 0.00 | | 0.5 | 0.00 | | 3 | 7.16 | 5 |
| 23 | 27Nov-3Dec2006 | 1 | 0.32 | 1 | 2.5 | 1.09 | 1 | 0.5 | 0.00 | | 0.5 | 0.00 | | 2.50 | 6.41 | 5 |

Table A-19 (Cont.)

| Week | Date | Canal 1R-1L-5L(Km.11+714) | | | Canal 1R-1L-5L(Km.29+234) | | | Canal 1R-1L-5L(km.32+620) | | | Canal 1R-1L-5L(km.36+976) | | | Canal 3L-1R-1L-5L | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Planned | Delivery | score | Planned | Delivery | score | Planned | Delivery | score | Planned | Delivery | score | Planned | Delivery | score |
| 4 | 17-23 Jul 2006 | | | | | | | | | | | | | 0.35 | 0.22 | 1 |
| 5 | 24-30 Jul 2006 | | | | | | | | | | | | | 0.35 | 0.22 | 1 |
| 6 | 31 Jul - 6 Aug 2006 | | | | 2.70 | 2.56 | 5 | 2 | 2.09 | 5 | 0.90 | 1.63 | 5 | 0.35 | 0.85 | 5 |
| 7 | 7-13 Aug 2006 | 6 | 4.93 | 3 | 2.7 | 2.53 | 5 | 2 | 2.28 | 5 | 1 | 1.67 | 5 | 0.35 | 0.88 | 5 |
| 8 | 14-20 Aug 2006 | 6 | 10.79 | 5 | 3 | 2.13 | 1 | 2.2 | 2.44 | 5 | 1 | 1.70 | 5 | 0.35 | 0.50 | 5 |
| 9 | 21-27 Aug 2006 | 6 | 10.39 | 5 | 2.8 | 2.25 | 3 | 2.4 | 2.71 | 5 | 1.1 | 1.85 | 5 | 0.3 | 0.67 | 5 |
| 10 | 28Aug -3Sep2006 | 6 | 9.52 | 5 | 2.4 | 2.28 | 5 | 2.3 | 3.03 | 5 | 0.7 | 1.79 | 5 | 0.3 | 0.21 | 1 |
| 11 | 4-10Sep2006 | 5 | 9.50 | 5 | 2 | 1.97 | 5 | 1.8 | 2.97 | 5 | 0.8 | 1.47 | 5 | 0.3 | 0.73 | 5 |
| 12 | 11-17Sep2006 | 4.5 | 9.43 | 5 | 2.5 | 2.08 | 4 | 1.6 | 2.97 | 5 | 0.8 | 1.56 | 5 | 0.3 | 0.89 | 5 |
| 13 | 18-24Sep2006 | 5.5 | 9.43 | 5 | 2.3 | 1.85 | 3 | 2 | 2.97 | 5 | 0.7 | 1.50 | 5 | 0.3 | 0.82 | 5 |
| 14 | 25Sep-1Oct2006 | 4.5 | 8.80 | 5 | 2.1 | 1.96 | 5 | 1.8 | 2.97 | 5 | 0.7 | 1.37 | 5 | 0.3 | 0.12 | 1 |
| 15 | 2-8Oct2006 | 4.5 | 8.86 | 5 | 2.1 | 2.31 | 5 | 1.6 | 2.78 | 5 | 0.7 | 1.42 | 5 | 0.3 | 0.21 | 1 |
| 16 | 9-15Oct2006 | 4.5 | 8.86 | 5 | 2.1 | 2.05 | 5 | 1.6 | 2.58 | 5 | 0.7 | 1.31 | 5 | 0.25 | 0.17 | 1 |
| 17 | 16-22Oct2006 | 4.5 | 8.86 | 5 | 2.1 | 2.04 | 5 | 1.6 | 2.24 | 5 | 0.7 | 1.24 | 5 | 0.25 | 0.00 | |
| 18 | 23-29Oct2006 | 3.5 | 8.86 | 5 | 2.1 | 2.04 | 5 | 1.6 | 2.24 | 5 | 0.5 | 1.26 | 5 | 0.25 | 0.00 | |
| 19 | 30Oct-5Nov2006 | 3 | 8.86 | 5 | 1.5 | 2.06 | 5 | 1.1 | 2.13 | 5 | 0.4 | 1.35 | 5 | 0.25 | 0.46 | 5 |
| 20 | 6-12Nov2006 | 3 | 8.86 | 5 | 1.4 | 2.04 | 5 | 1 | 2.09 | 5 | 0.4 | 1.42 | 5 | 0.25 | 0.56 | 5 |
| 21 | 13-19Nov2006 | 3.5 | 8.86 | 5 | 1.4 | 0.74 | 1 | 1 | 1.90 | 5 | 0.3 | 0.38 | 5 | 0.3 | 0.49 | 5 |
| 22 | 20-26Nov2006 | 2.5 | 8.86 | 5 | 1.6 | 0.00 | | 1 | 0.27 | 1 | 0.1 | 0.00 | | 0.3 | 0.50 | 5 |
| 23 | 27Nov-3Dec2006 | 1.50 | 8.86 | 5 | 0.77 | 0.00 | | 1 | 0.00 | | 0.10 | 0.00 | | 0.20 | 0.31 | 5 |

Table A-19 (Cont.)

| Week | Date | Canal 4L-1R-1L-5L | | | Canal 5L-1R-1L-5L | | | Canal 6L-1R-1L-5L | | | Canal 7L-1R-1L-5L | | | Canal 8L-1R-1L-5L | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Planned | Delivery | score | Planned | Delivery | score | Planned | Delivery | score | Planned | Delivery | score | Planned | Delivery | score |
| 4 | 17-23 Jul 2006 | 0.4 | 0.23 | 1 | | 0.00 | | 0.5 | 0.38 | 2 | 0.2 | 0.12 | 1 | 0.7 | 0.47 | 1 |
| 5 | 24-30 Jul 2006 | 0.4 | 0.56 | 5 | 0.35 | 0.13 | 1 | 0.5 | 0.53 | 5 | 0.2 | 0.14 | 1 | 0.7 | 0.47 | 1 |
| 6 | 31 Jul - 6 Aug 2006 | 0.4 | 0.38 | 5 | 0.35 | 0.26 | 2 | 0.5 | 0.60 | 5 | 0.2 | 0.14 | 1 | 0.7 | 0.47 | 1 |
| 7 | 7-13 Aug 2006 | 0.4 | 0.23 | 1 | 0.35 | 0.25 | 1 | 0.5 | 0.57 | 5 | 0.2 | 0.13 | 1 | 0.7 | 0.47 | 1 |
| 8 | 14-20 Aug 2006 | 0.4 | 0.35 | 4 | 0.3 | 0.24 | 3 | 0.5 | 0.59 | 5 | 0.2 | 0.13 | 1 | 0.8 | 0.55 | 1 |
| 9 | 21-27 Aug 2006 | 0.4 | 0.19 | 1 | 0.3 | 0.21 | 1 | 0.5 | 0.58 | 5 | 0.2 | 0.13 | 1 | 0.8 | 0.55 | 1 |
| 10 | 28Aug -3Sep2006 | 0.4 | 0.00 | 1 | 0.3 | 0.13 | 1 | 0.5 | 0.58 | 5 | 0.2 | 0.14 | 1 | 0.7 | 0.55 | 3 |
| 11 | 4-10Sep2006 | 0.35 | 0.00 | 1 | 0.3 | 0.21 | 1 | 0.5 | 0.55 | 5 | 0.2 | 0.13 | 1 | 0.6 | 0.55 | 5 |
| 12 | 11-17Sep2006 | 0.4 | 0.08 | 1 | 0.3 | 0.22 | 1 | 0.4 | 0.37 | 5 | 0.2 | 0.13 | 1 | 0.6 | 0.55 | 5 |
| 13 | 18-24Sep2006 | 0.35 | 0.00 | 1 | 0.3 | 0.22 | 1 | 0.5 | 0.27 | 1 | 0.2 | 0.06 | 1 | 0.7 | 0.55 | 3 |
| 14 | 25Sep-1Oct2006 | 0.35 | 0.00 | 1 | 0.3 | 0.19 | 1 | 0.4 | 0.28 | 1 | 0.2 | 0.02 | 1 | 0.6 | 0.47 | 3 |
| 15 | 2-8Oct2006 | 0.35 | 0.00 | 1 | 0.3 | 0.19 | 1 | 0.4 | 0.35 | 4 | 0.2 | 0.13 | 1 | 0.6 | 0.39 | 1 |
| 16 | 9-15Oct2006 | 0.35 | 0.00 | 1 | 0.3 | 0.19 | 1 | 0.4 | 0.03 | 1 | 0.2 | 0.13 | 1 | 0.6 | 0.39 | 1 |
| 17 | 16-22Oct2006 | 0.35 | 0.00 | 1 | 0.3 | 0.17 | 1 | 0.4 | 0.00 | 1 | 0.2 | 0.09 | 1 | 0.6 | 0.39 | 1 |
| 18 | 23-29Oct2006 | 0.3 | 0.00 | 1 | 0.3 | 0.00 | 1 | 0.3 | 0.00 | 1 | 0.15 | 0.00 | 1 | 0.4 | 0.55 | 5 |
| 19 | 30Oct-5Nov2006 | 0.25 | 0.42 | 5 | 0.2 | 0.15 | 2 | 0.25 | 0.36 | 5 | 0.2 | 0.09 | 1 | 0.3 | 0.55 | 5 |
| 20 | 6-12Nov2006 | 0.4 | 0.49 | 5 | 0.2 | 0.20 | 5 | 0.25 | 0.52 | 5 | 0.2 | 0.12 | 1 | 0.3 | 0.55 | 5 |
| 21 | 13-19Nov2006 | 0.25 | 0.28 | 5 | 0.2 | 0.20 | 5 | 0.4 | 0.53 | 5 | 0.2 | 0.13 | 1 | 0.3 | 0.39 | 5 |
| 22 | 20-26Nov2006 | 0.25 | 0.00 | 1 | 0.3 | 0.03 | 1 | 0.35 | 0.53 | 5 | 0.2 | 0.13 | 1 | 0.1 | 0.39 | 5 |
| 23 | 27Nov-3Dec2006 | 0.40 | 0.00 | 1.00 | 0.25 | 0.00 | | 0.20 | 0.30 | 5 | 0.2 | 0.07 | 1 | 0.00 | 0.24 | 5 |

Table A-19 (Cont.)

| Week | Date | Canal 2R-1R-1L-5L | | | Canal 2R-1R-1L-5L (Km.15+000) | | | Canal 2R-2R-1R-1L-5L | | | Canal 3R-2R-1R-1L-5L | | | Canal 4R-2R-1R-1L-5L | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Planned | Delivery | score | Planned | Delivery | score | Planned | Delivery | score | Planned | Delivery | score | Planned | Delivery | score |
| 4 | 17-23 Jul 2006 | 4 | 2.6 | 1 | 1 | 1.1 | 5 | 0.2 | 0.3 | 5 | 0.2 | 0.1 | 1 | 0.8 | 1.2 | 5 |
| 5 | 24-30 Jul 2006 | 4 | 3.6 | 4 | 1 | 1.1 | 5 | 0.2 | 0.4 | 5 | 0.2 | 0.1 | 1 | 0.8 | 1.3 | 5 |
| 6 | 31 Jul - 6 Aug 2006 | 4 | 3.7 | 5 | 1 | 0.9 | 4 | 0.2 | 0.3 | 5 | 0.2 | 0.1 | 1 | 0.8 | 1.2 | 5 |
| 7 | 7-13 Aug 2006 | 4 | 3.6 | 5 | 1 | 0.9 | 5 | 0.2 | 0.3 | 5 | 0.2 | 0.2 | 5 | 0.8 | 1.1 | 5 |
| 8 | 14-20 Aug 2006 | 4 | 4.0 | 5 | 1 | 0.7 | 1 | 0.2 | 0.3 | 5 | 0.2 | 0.2 | 3 | 0.8 | 1.1 | 5 |
| 9 | 21-27 Aug 2006 | 4 | 3.4 | 4 | 1 | 0.7 | 2 | 0.2 | 0.1 | 1 | 0.2 | 0.1 | 1 | 0.8 | 1.0 | 5 |
| 10 | 28Aug -3Sep2006 | 4 | 2.5 | 1 | 1 | 0.7 | 2 | 0.2 | 0.0 | 1 | 0.2 | 0.0 | 1 | 0.8 | 0.9 | 5 |
| 11 | 4-10Sep2006 | 4 | 2.4 | 1 | 1 | 0.5 | 1 | 0.2 | 0.2 | 5 | 0.2 | 0.0 | 1 | 0.8 | 0.8 | 5 |
| 12 | 11-17Sep2006 | 4 | 2.7 | 1 | 1 | 0.7 | 1 | 0.2 | 0.3 | 3 | 0.2 | 0.0 | 1 | 0.8 | 1.4 | 5 |
| 13 | 18-24Sep2006 | 4 | 2.2 | 1 | 1 | 0.7 | 1 | 0.2 | 0.1 | 1 | 0.2 | 0.1 | 1 | 0.8 | 1.3 | 5 |
| 14 | 25Sep-1Oct2006 | 4 | 2.0 | 1 | 1 | 0.7 | 1 | 0.2 | 0.1 | 1 | 0.2 | 0.1 | 1 | 0.8 | 1.3 | 5 |
| 15 | 2-8Oct2006 | 4 | 1.7 | 1 | 1 | 0.9 | 4 | 0.2 | 0.2 | 4 | 0.2 | 0.0 | 1 | 0.8 | 0.3 | 1 |
| 16 | 9-15Oct2006 | 4 | 1.5 | 1 | 1 | 0.6 | 1 | 0.2 | 0.3 | 5 | 0.2 | 0.0 | | 0.8 | 1.1 | 5 |
| 17 | 16-22Oct2006 | 4 | 1.4 | 1 | 1 | 0.6 | 1 | 0.2 | 0.3 | 5 | 0.2 | 0.0 | | 0.8 | 1.1 | 5 |
| 18 | 23-29Oct2006 | 4 | 2.3 | 1 | 1 | 0.5 | 1 | 0.2 | 0.3 | 5 | 0.2 | 0.0 | 1 | 0.8 | 0.9 | 5 |
| 19 | 30Oct-5Nov2006 | 4 | 3.2 | 3 | 1 | 0.5 | 1 | 0.2 | 0.3 | 5 | 0.2 | 0.1 | 1 | 0.8 | 0.9 | 5 |
| 20 | 6-12Nov2006 | 4 | 3.0 | 2 | 1 | 0.6 | 1 | 0.2 | 0.3 | 5 | 0.2 | 0.1 | 1 | 0.8 | 0.9 | 5 |
| 21 | 13-19Nov2006 | 4 | 3.4 | 4 | 1 | 0.5 | 1 | 0.2 | 0.3 | 5 | 0.2 | 0.1 | 1 | 0.8 | 0.7 | 4 |
| 22 | 20-26Nov2006 | 4 | 2.8 | 1 | 1 | 0.4 | 1 | 0.2 | 0.3 | 5 | 0.2 | 0.0 | | 0.8 | 0.8 | 5 |
| 23 | 27Nov-3Dec2006 | 4 | 2.4 | 1 | 1 | 0.3 | 1 | 0.2 | 0.3 | 5 | 0.2 | 0.0 | | 0.8 | 0.5 | 1 |

Table A-19 (Cont.)

| Week | Date | Canal 5R-2R-1R-1L-5L | | | Canal 2L-5L | | | Canal 2L-5L(Km.10+920) | | | Canal 2L-5L(Km.18+210) | | | Canal 2L-5L(Km.26+900) | | | Canal 1L-2L-5L | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Planned | Delivery | score | Planned | Delivery | score | Planned | Delivery | score | Planned | Delivery | score | Planned | Delivery | score | Planned | Delivery | score |
| 4 | 17-23 Jul 2006 | 0.2 | 0.2 | 5 | 6 | 4.9 | 3 | 1.5 | 3.1 | 5 | 1 | 1.7 | 5 | 1 | 0.7 | 1 | 0.7 | 0.6 | 3 |
| 5 | 24-30 Jul 2006 | 0.2 | 0.3 | 5 | 6 | 5.7 | 5 | 1.5 | 3.1 | 5 | 1 | 1.7 | 5 | 1 | 0.7 | 1 | 0.7 | 0.7 | 5 |
| 6 | 31 Jul - 6 Aug 2006 | 0.2 | 0.3 | 5 | 6 | 6.0 | 5 | 1.5 | 3.9 | 5 | 1 | 1.4 | 5 | 1 | 0.5 | 1 | 0.7 | 0.3 | 1 |
| 7 | 7-13 Aug 2006 | 0.2 | 0.3 | 5 | 6 | 5.9 | 5 | 1.5 | 4.8 | 5 | 1 | 1.7 | 5 | 1 | 0.8 | 3 | 0.7 | 0.3 | 1 |
| 8 | 14-20 Aug 2006 | 0.2 | 0.3 | 5 | 6 | 6.3 | 5 | 1.5 | 3.3 | 5 | 1 | 2.4 | 5 | 1 | 0.8 | 3 | 0.7 | 0.3 | 1 |
| 9 | 21-27 Aug 2006 | 0.2 | 0.3 | 5 | 6 | 5.9 | 5 | 1.5 | 3.0 | 5 | 1 | 2.4 | 5 | 1 | 0.8 | 4 | 0.7 | 0.3 | 1 |
| 10 | 28Aug -3Sep2006 | 0.2 | 0.4 | 5 | 6 | 4.7 | 3 | 1.5 | 3.2 | 5 | 1 | 2.1 | 5 | 1 | 0.8 | 2 | 0.7 | 0.3 | 1 |
| 11 | 4-10Sep2006 | 0.2 | 0.2 | 5 | 6 | 4.2 | 1 | 1.5 | 3.7 | 5 | 1 | 1.9 | 5 | 1 | 0.3 | 1 | 0.7 | 0.3 | 1 |
| 12 | 11-17Sep2006 | 0.2 | 0.2 | 5 | 6 | 5.1 | 4 | 1.5 | 3.6 | 5 | 1 | 1.7 | 5 | 1 | 1.0 | 5 | 0.7 | 0.3 | 1 |
| 13 | 18-24Sep2006 | 0.2 | 0.2 | 5 | 6 | 4.2 | 1 | 1.5 | 3.0 | 5 | 1 | 1.7 | 5 | 1 | 0.5 | 1 | 0.7 | 0.3 | 1 |
| 14 | 25Sep-1Oct2006 | 0.2 | 0.2 | 5 | 6 | 3.7 | 1 | 1.5 | 2.8 | 5 | 1 | 1.7 | 5 | 1 | 0.6 | 1 | 0.7 | 0.3 | 1 |
| 15 | 2-8Oct2006 | 0.2 | 0.2 | 5 | 6 | 4.2 | 1 | 1.5 | 2.8 | 5 | 1 | 0.9 | 5 | 1 | 0.4 | 1 | 0.7 | 0.3 | 1 |
| 16 | 9-15Oct2006 | 0.2 | 0.2 | 5 | 6 | 4.8 | 3 | 1.5 | 2.1 | 5 | 1 | 1.0 | 5 | 1 | 0.8 | 3 | 0.7 | 0.3 | 1 |
| 17 | 16-22Oct2006 | 0.2 | 0.2 | 5 | 6 | 4.4 | 2 | 1.5 | 1.9 | 5 | 1 | 1.1 | 5 | 1 | 0.7 | 1 | 0.7 | 0.1 | 1 |
| 18 | 23-29Oct2006 | 0.2 | 0.2 | 5 | 6 | 3.6 | 1 | 1.5 | 1.9 | 5 | 1 | 1.2 | 5 | 1 | 0.4 | 1 | 0.7 | 0.5 | 1 |
| 19 | 30Oct-5Nov2006 | 0.2 | 0.2 | 3 | 6 | 5.6 | 5 | 1.5 | 3.4 | 5 | 1 | 1.1 | 5 | 1 | 0.3 | 1 | 0.7 | 0.8 | 5 |
| 20 | 6-12Nov2006 | 0.2 | 0.1 | 1 | 6 | 4.6 | 3 | 1.5 | 2.2 | 5 | 1 | 1.2 | 5 | 1 | 0.7 | 1 | 0.7 | 0.7 | 5 |
| 21 | 13-19Nov2006 | 0.2 | 0.1 | 1 | 6 | 2.1 | 1 | 1.5 | 1.4 | 5 | 1 | 0.3 | 1 | 1 | 0.2 | 1 | 0.7 | 0.7 | 5 |
| 22 | 20-26Nov2006 | 0.2 | 0.1 | 1 | 6 | 3.1 | 1 | 1.5 | 1.2 | 3 | 1 | 0.3 | 1 | 1 | 0.1 | 1 | 0.7 | 0.7 | 5 |
| 23 | 27Nov-3Dec2006 | 0.2 | | | 6 | 3.5 | 1 | 0.60 | 2.1 | 5 | 1 | 0.5 | 1 | 1 | 0.0 | | 0.7 | 0.5 | 1 |

Table A-20 Planned and Delivered Flow on Weekly Plan in KPP (Dry Season)

| Week | Date | Canal 3L | | | Canal 4L | | | Canal 4L(Km.3+100) | | | Canal 1L-4L | | | Canal 1L - 5L | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Planned | Delivered | score | Planned | Delivered | score | Planned | Delivered | score | Planned | Delivered | score | Planned | Delivered | score |
| 5 | 29 Jan -4Feb2007 | | | | | | | 0.5 | 0.50 | 5 | | | | | | |
| 6 | 5-11Feb2007 | | | | | | | 0.5 | 0.80 | 5 | | | | 3 | 9.99 | 5 |
| 7 | 12-18Feb2007 | 1 | 0.53 | 1 | 2.5 | 1.23 | 1 | 0.5 | 0.75 | 5 | 0.5 | 0.40 | 3 | 3 | 9.91 | 5 |
| 8 | 19-25Feb2007 | 1 | 0.56 | 1 | 2.5 | 2.43 | 5 | 0.5 | 0.73 | 5 | 0.5 | 1.38 | 5 | 3 | 11.06 | 5 |
| 9 | 26Feb-4Mar2007 | 1 | 0.62 | 1 | 2.5 | 2.50 | 5 | 0.8 | 0.83 | 5 | 0.5 | 0.62 | 5 | 3 | 12.66 | 5 |
| 10 | 5-11Mar2007 | 1 | 0.65 | 1 | 2.5 | 2.11 | 4 | 0.8 | 0.64 | 3 | 0.5 | 0.00 | | 3 | 13.12 | 5 |
| 11 | 12-18Mar2007 | 1 | 0.64 | 1 | 2.5 | 1.55 | 1 | 0.8 | 0.54 | 1 | 0.5 | 0.00 | | 3 | 12.75 | 5 |
| 12 | 19-25Mar2007 | 1 | 0.54 | 1 | 2.5 | 2.10 | 4 | 0.8 | 0.62 | 3 | 0.5 | 0.00 | | 3 | 11.58 | 5 |
| 13 | 26Mar-1Apr2007 | 1 | 0.66 | 1 | 2.5 | 2.19 | 4 | 1 | 0.62 | 1 | 0.5 | 0.20 | 1 | 2.5 | 12.16 | 5 |
| 14 | 2-8Apr2007 | 1 | 0.67 | 1 | 2.5 | 2.51 | 5 | 1 | 0.76 | 2 | 0.5 | 1.40 | 5 | 2.5 | 13.03 | 5 |
| 15 | 9-15Apr2007 | 1 | 0.63 | 1 | 2.5 | 2.09 | 4 | 1 | 0.65 | 1 | 0.5 | 1.40 | 5 | 2.5 | 12.37 | 5 |
| 16 | 16-22Apr2007 | 1 | 0.49 | 1 | 2.5 | 2.16 | 4 | 0.8 | 0.65 | 3 | 0.5 | 1.40 | 5 | 3.0 | 10.84 | 5 |
| 17 | 23-29Apr2007 | 1 | 0.61 | 1 | 2.5 | 2.31 | 5 | 0.8 | 0.65 | 3 | 0.5 | 1.40 | 5 | 3.0 | 12.81 | 5 |
| 18 | 30Apr-6May2007 | 1 | 0.22 | 1 | 2.5 | 1.63 | 1 | 0.8 | 0.53 | 1 | 0.5 | 1.40 | 5 | 3.0 | 7.11 | 5 |
| 19 | 7-13May2007 | 1 | 0.00 | 1 | 2.5 | 0.75 | 1 | 0.8 | 0.53 | 1 | 0.5 | 1.40 | 5 | 3.0 | 3.02 | 5 |
| 20 | 14-20May2007 | 1 | 0.00 | 1 | 2.5 | 0.12 | 1 | 0.8 | 0.15 | 1 | 0.5 | 1.40 | 5 | 3.0 | 2.37 | 5 |
| 21 | 21-27May2007 | 1 | 0.43 | 1 | 2.5 | 1.36 | 1 | 0.8 | 0.38 | 1 | 0.5 | 1.40 | 5 | 3.0 | 6.83 | 5 |
| 22 | 28May-3Jun2007 | 1 | 0.32 | 1 | 2.5 | 1.18 | 1 | 0.8 | 0.30 | 1 | 0.5 | 0.80 | 5 | 3.0 | 5.47 | 5 |

Table A-20 (Cont.)

| Week | Date | Canal 1R-1L-5L(Km.11+714) | | | Canal 1R-1L-5L(Km.29+234) | | | Canal 1R-1L-5L(km.32+620) | | | Canal 1R-1L-5L(km.36+976) | | | Canal 3L-1R-1L-5L | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Planned | Delivery | score | Planned | Delivery | score | Planned | Delivery | score | Planned | Delivery | score | Planned | Delivery | score |
| 5 | 29 Jan -4Feb2007 | | | | | | | | | | | | | | | |
| 6 | 5-11Feb2007 | | | | | 1.32 | | | 0.81 | | | 0.54 | | 0.8 | 0.31 | 1 |
| 7 | 12-18Feb2007 | 5.09 | 5.74 | 5 | 2.55 | 2.28 | 4 | 1.78 | 1.63 | 5 | 0.76 | 1.31 | 5 | 0.8 | 0.49 | 1 |
| 8 | 19-25Feb2007 | 7.688 | 6.70 | 4 | 3.84 | 2.38 | 1 | 2.69 | 1.90 | 1 | 1.15 | 1.69 | 5 | 0.8 | 0.57 | 2 |
| 9 | 26Feb-4Mar2007 | 8.695 | 6.70 | 2 | 4.35 | 3.42 | 3 | 3.04 | 1.90 | 1 | 1.30 | 2.12 | 5 | 0.8 | 0.50 | 1 |
| 10 | 5-11Mar2007 | 6.993 | 6.70 | 5 | 3.50 | 3.19 | 5 | 2.45 | 1.90 | 3 | 1.05 | 2.46 | 5 | 0.8 | 0.46 | 1 |
| 11 | 12-18Mar2007 | 6.993 | 6.70 | 5 | 3.50 | 3.45 | 5 | 2.45 | 1.90 | 3 | 1.05 | 2.53 | 5 | 0.8 | 0.42 | 1 |
| 12 | 19-25Mar2007 | 6.993 | 6.70 | 5 | 3.50 | 3.52 | 5 | 2.45 | 1.90 | 3 | 1.05 | 2.47 | 5 | 0.8 | 0.48 | 1 |
| 13 | 26Mar-1Apr2007 | 6.993 | 6.70 | 5 | 3.50 | 3.00 | 4 | 2.45 | 1.90 | 3 | 1.05 | 2.44 | 5 | 0.8 | 0.41 | 1 |
| 14 | 2-8Apr2007 | 9.076 | 6.70 | 2 | 4.54 | 2.46 | 1 | 3.18 | 1.90 | 1 | 1.36 | 2.09 | 5 | 0.8 | 0.32 | 1 |
| 15 | 9-15Apr2007 | 6.993 | 6.70 | 5 | 3.50 | 3.64 | 5 | 2.45 | 1.90 | 3 | 1.05 | 2.25 | 5 | 0.8 | 0.28 | 1 |
| 16 | 16-22Apr2007 | 6.993 | 6.70 | 5 | 3.50 | 3.10 | 4 | 2.45 | 1.90 | 3 | 1.05 | 1.53 | 5 | 0.8 | 0.45 | 1 |
| 17 | 23-29Apr2007 | 6.993 | 6.70 | 5 | 3.50 | 2.82 | 3 | 2.45 | 1.90 | 3 | 1.05 | 1.97 | 5 | 0.8 | 0.47 | 1 |
| 18 | 30Apr-6May2007 | 6.186 | 6.70 | 5 | 3.09 | 2.84 | 5 | 2.17 | 1.90 | 4 | 0.93 | 2.10 | 5 | 0.8 | 0.23 | 1 |
| 19 | 7-13May2007 | 6.186 | 6.70 | 5 | 3.09 | 2.80 | 5 | 2.17 | 1.90 | 4 | 0.93 | 0.86 | 5 | 0.8 | 0.24 | 1 |
| 20 | 14-20May2007 | 5.726 | 6.70 | 5 | 2.86 | 2.80 | 5 | 2.00 | 1.90 | 5 | 0.86 | 1.04 | 5 | 0.8 | 0.24 | 1 |
| 21 | 21-27May2007 | 4.042 | 6.70 | 5 | 2.02 | 2.80 | 5 | 1.41 | 1.90 | 5 | 0.61 | 1.11 | 5 | 0.8 | 0.26 | 1 |
| 22 | 28May-3Jun2007 | 2.44 | 3.83 | 5 | 1.22 | 1.60 | 5 | 0.85 | 1.09 | 5 | 0.37 | 1.36 | 5 | 0.5 | 0.20 | 1 |

Table A-20 (Cont.)

| Week | Date | Canal 4L-1R-1L-5L | | | Canal 5L-1R-1L-5L | | | Canal 6L-1R-1L-5L | | | Canal 7L-1R-1L-5L | | | Canal 8L-1R-1L-5L | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Planned | Delivery | score | Planned | Delivery | score | Planned | Delivery | score | Planned | Delivery | score | Planned | Delivery | score |
| 5 | 29 Jan -4Feb2007 | | | | | | | | 0.00 | | | | | | | |
| 6 | 5-11Feb2007 | | | | | | | | 0.25 | | | 0.09 | | | | |
| 7 | 12-18Feb2007 | 1.017 | 0.37 | 1 | 0.23 | 0.13 | 1 | 0.35 | 0.57 | 5 | 0.37 | 0.11 | 1 | 2.14 | 0.86 | 1 |
| 8 | 19-25Feb2007 | 0.935 | 0.40 | 1 | 0.907 | 0.30 | 1 | 1.00 | 0.68 | 1 | 0.69 | 0.13 | 1 | 1.54 | 0.86 | 1 |
| 9 | 26Feb-4Mar2007 | 1.004 | 0.54 | 1 | 0.345 | 0.31 | 5 | 0.35 | 0.46 | 5 | 0.69 | 0.14 | 1 | 2.31 | 0.86 | 1 |
| 10 | 5-11Mar2007 | 0.808 | 0.37 | 1 | 1.548 | 0.35 | 1 | 0.81 | 0.58 | 2 | 0.69 | 0.14 | 1 | 2.51 | 0.86 | 1 |
| 11 | 12-18Mar2007 | 0.808 | 0.34 | 1 | 0.909 | 0.39 | 1 | 1.19 | 0.66 | 1 | 0.69 | 0.14 | 1 | 2.51 | 0.86 | 1 |
| 12 | 19-25Mar2007 | 0.808 | 0.27 | 1 | 0.909 | 0.38 | 1 | 1.19 | 0.65 | 1 | 0.69 | 0.14 | 1 | 2.51 | 0.86 | 1 |
| 13 | 26Mar-1Apr2007 | 0.889 | 0.36 | 1 | 0.886 | 0.32 | 1 | 0.91 | 0.61 | 1 | 0.69 | 0.13 | 1 | 2.51 | 0.86 | 1 |
| 14 | 2-8Apr2007 | 1.014 | 0.56 | 1 | 0.813 | 0.31 | 1 | 3.02 | 0.62 | 2 | 0.69 | 0.13 | 1 | 2.51 | 0.86 | 1 |
| 15 | 9-15Apr2007 | 0.808 | 0.11 | 1 | 0.909 | 0.31 | 1 | 1.19 | 0.48 | 1 | 0.69 | 0.13 | 1 | 2.51 | 0.86 | 1 |
| 16 | 16-22Apr2007 | 0.8 | 0.26 | 1 | 0.9 | 0.31 | 1 | 1.19 | 0.45 | 1 | 0.69 | 0.13 | 1 | 2.51 | 0.86 | 1 |
| 17 | 23-29Apr2007 | 0.8 | 0.53 | 1 | 0.9 | 0.31 | 1 | 1.19 | 0.46 | 1 | 0.69 | 0.13 | 1 | 2.51 | 0.86 | 1 |
| 18 | 30Apr-6May2007 | 0.8 | 0.43 | 1 | 0.9 | 0.18 | 1 | 1.19 | 0.43 | 1 | 0.69 | 0.13 | 1 | 1.92 | 0.86 | 1 |
| 19 | 7-13May2007 | 0.8 | 0.40 | 1 | 0.9 | 0.18 | 1 | 1.19 | 0.00 | | 0.69 | 0.13 | 1 | 1.92 | 0.86 | 1 |
| 20 | 14-20May2007 | 0.8 | 0.40 | 1 | 0.5 | 0.22 | 1 | 1.19 | 0.19 | 1 | 0.69 | 0.13 | 1 | 1.96 | 0.86 | 1 |
| 21 | 21-27May2007 | 0.8 | 0.39 | 1 | 0.5 | 0.18 | 1 | 1.19 | 0.39 | 1 | 0.69 | 0.13 | 1 | 1.14 | 0.61 | 1 |
| 22 | 28May-3Jun2007 | 0.5 | 0.26 | 1 | 0.3 | 0.18 | 1 | 6.08 | 0.36 | 1 | 0.47 | 0.07 | 1 | 0.58 | 0.61 | 5 |

Table A-20 (Cont.)

| Week | Date | Canal 2R-1R-1L-5L | | | Canal 2R-1R-1L-5L (Km.15+000) | | | Canal 2R-2R-1R-1L-5L | | | Canal 3R-2R-1R-1L-5L | | | Canal 4R-2R-1R-1L-5L | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Planned | Delivery | score | Planned | Delivery | score | Planned | Delivery | score | Planned | Delivery | score | Planned | Delivery | score |
| 5 | 29 Jan -4Feb2007 | | | | 1 | | | | | | | | | | | |
| 6 | 5-11Feb2007 | 4 | 2.0 | 1 | 1 | 0.9 | 4 | 0.2 | 0.5 | 5 | 0.2 | 0.4 | 5 | 0.8 | 0.6 | 3 |
| 7 | 12-18Feb2007 | 4 | 2.7 | 1 | 1 | 1.1 | 5 | 0.2 | 0.5 | 5 | 0.2 | 0.3 | 5 | 0.8 | 0.7 | 4 |
| 8 | 19-25Feb2007 | 4 | 3.3 | 4 | 1 | 1.2 | 5 | 0.2 | 0.5 | 5 | 0.2 | 0.3 | 5 | 0.8 | 0.8 | 5 |
| 9 | 26Feb-4Mar2007 | 4 | 3.7 | 5 | 1 | 1.3 | 5 | 0.2 | 0.5 | 5 | 0.2 | 0.4 | 5 | 0.8 | 1.0 | 5 |
| 10 | 5-11Mar2007 | 4 | 3.7 | 5 | 1 | 1.2 | 5 | 0.2 | 0.5 | 5 | 0.2 | 0.3 | 5 | 0.8 | 1.1 | 5 |
| 11 | 12-18Mar2007 | 4.5 | 4.7 | 5 | 1 | 1.2 | 5 | 0.2 | 0.5 | 5 | 0.2 | 0.3 | 5 | 0.8 | 1.1 | 5 |
| 12 | 19-25Mar2007 | 4 | 4.0 | 5 | 1 | 1.1 | 5 | 0.2 | 0.4 | 5 | 0.2 | 0.2 | 5 | 0.8 | 1.2 | 5 |
| 13 | 26Mar-1Apr2007 | 4 | 3.1 | 3 | 1 | 1.1 | 5 | 0.2 | 0.4 | 5 | 0.2 | 0.2 | 4 | 0.8 | 1.3 | 5 |
| 14 | 2-8Apr2007 | 4 | 3.1 | 3 | 1 | 1.0 | 5 | 0.2 | 0.4 | 5 | 0.2 | 0.1 | 1 | 0.8 | 1.1 | 5 |
| 15 | 9-15Apr2007 | 4 | 3.8 | 5 | 1 | 1.2 | 5 | 0.2 | 0.4 | 5 | 0.2 | 0.1 | 1 | 0.8 | 1.2 | 5 |
| 16 | 16-22Apr2007 | 4 | 3.2 | 3 | 1 | 1.0 | 5 | 0.2 | 0.3 | 5 | 0.2 | 0.1 | 1 | 0.8 | 1.1 | 5 |
| 17 | 23-29Apr2007 | 4 | 3.8 | 5 | 1 | 1.1 | 5 | 0.2 | 0.3 | 5 | 0.2 | 0.1 | 1 | 0.8 | 1.0 | 5 |
| 18 | 30Apr-6May2007 | 4 | 2.8 | 1 | 1 | 0.9 | 5 | 0.2 | 0.3 | 5 | 0.2 | 0.2 | 3 | 0.8 | 1.0 | 5 |
| 19 | 7-13May2007 | 4 | 2.6 | 1 | 1 | 0.4 | 1 | 0.2 | 0.3 | 5 | 0.2 | 0.0 | 1 | 0.8 | 0.7 | 5 |
| 20 | 14-20May2007 | 4 | 2.6 | 1 | 1 | 0.4 | 1 | 0.2 | 0.3 | 5 | 0.2 | 0.0 | | 0.8 | 0.6 | 3 |
| 21 | 21-27May2007 | 4 | 2.2 | 1 | 1 | 0.5 | 1 | 0.2 | 0.3 | 5 | 0.2 | 0.6 | 5 | 0.8 | 0.7 | 4 |
| 22 | 28May-3Jun2007 | 4 | 1.9 | 1 | 1 | 0.4 | 1 | 0.2 | 0.1 | 2 | 0.2 | 0.5 | 5 | 0.8 | 0.5 | 1 |

Table A-20 (Cont.)

| Week | Date | Canal 5R-2R-1R-1L-5L | | | Canal 2L-5L | | | Canal 2L-5L(Km.10+920) | | | Canal 2L-5L(Km.18+210) | | | Canal 2L-5L(Km.26+900) | | | Canal 1L-2L-5L | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Planned | Delivery | score | Planned | Delivery | score | Planned | Delivery | score | Planned | Delivery | score | Planned | Delivery | score | Planned | Delivery | score |
| 5 | 29 Jan -4Feb2007 | | | | | | | | | | | | | | | | | | |
| 6 | 5-11Feb2007 | 0.2 | 0.2 | 5 | 6 | 4.3 | 2 | 1.5 | 1.5 | 5 | 1 | 1.3 | 5 | 1 | 0.4 | 1 | 0.7 | 0.8 | 5 |
| 7 | 12-18Feb2007 | 0.2 | 0.4 | 5 | 6 | 5.7 | 5 | 1.5 | 3.5 | 5 | 1 | 1.2 | 5 | 1 | 0.8 | 2 | 0.7 | 0.8 | 5 |
| 8 | 19-25Feb2007 | 0.2 | 0.4 | 5 | 6 | 6.4 | 5 | 1.5 | 3.8 | 5 | 1 | 2.1 | 5 | 1 | 1.1 | 5 | 0.7 | 0.7 | 5 |
| 9 | 26Feb-4Mar2007 | 0.2 | 0.5 | 5 | 6 | 7.0 | 5 | 1.5 | 3.2 | 5 | 1 | 2.1 | 5 | 1 | 0.9 | 4 | 0.7 | 0.8 | 5 |
| 10 | 5-11Mar2007 | 0.2 | 0.3 | 5 | 6 | 7.4 | 5 | 1.5 | 2.6 | 5 | 1 | 2.0 | 5 | 1 | 0.9 | 4 | 0.7 | 0.7 | 5 |
| 11 | 12-18Mar2007 | 0.2 | 0.3 | 5 | 6.5 | 6.2 | 5 | 1.5 | 3.3 | 5 | 1 | 1.4 | 5 | 1 | 0.7 | 2 | 0.7 | 0.8 | 5 |
| 12 | 19-25Mar2007 | 0.2 | 0.3 | 5 | 6.5 | 5.5 | 4 | 1.5 | 3.0 | 5 | 1 | 1.2 | 5 | 1 | 0.6 | 1 | 0.7 | 1.1 | 5 |
| 13 | 26Mar-1Apr2007 | 0.2 | 0.2 | 5 | 6 | 5.5 | 5 | 1.5 | 3.5 | 5 | 1 | 1.6 | 5 | 1 | 0.3 | 1 | 0.7 | 0.9 | 5 |
| 14 | 2-8Apr2007 | 0.2 | 0.2 | 5 | 6 | 7.0 | 5 | 1.5 | 4.2 | 5 | 1 | 1.8 | 5 | 1 | 0.4 | 1 | 0.7 | 0.7 | 5 |
| 15 | 9-15Apr2007 | 0.2 | 0.2 | 5 | 6 | 7.0 | 5 | 1.5 | 4.2 | 5 | 1 | 2.1 | 5 | 1 | 0.9 | 5 | 0.7 | 0.7 | 5 |
| 16 | 16-22Apr2007 | 0.2 | 0.2 | 5 | 6 | 6.5 | 5 | 1.5 | 3.9 | 5 | 1 | 1.3 | 5 | 1 | 0.8 | 2 | 0.7 | 0.7 | 5 |
| 17 | 23-29Apr2007 | 0.2 | 0.2 | 5 | 6 | 6.2 | 5 | 1.5 | 3.8 | 5 | 1 | 1.2 | 5 | 1 | 0.5 | 1 | 0.7 | 0.7 | 5 |
| 18 | 30Apr-6May2007 | 0.2 | 0.3 | 5 | 6 | 3.1 | 1 | 1.5 | 3.8 | 5 | 1 | 1.2 | 5 | 1 | 0.6 | 1 | 0.7 | 0.7 | 5 |
| 19 | 7-13May2007 | 0.2 | 0.2 | 4 | 6 | 2.1 | 1 | 1.5 | 3.4 | 5 | 1 | 1.3 | 5 | 1 | 0.5 | 1 | 0.7 | 0.1 | 1 |
| 20 | 14-20May2007 | 0.2 | 0.1 | 1 | 6 | 2.6 | 1 | 1.5 | 3.4 | 5 | 1 | 1.3 | 5 | 1 | 0.3 | 1 | 0.7 | 0.0 | |
| 21 | 21-27May2007 | 0.2 | 0.2 | 1 | 6 | 2.4 | 1 | 1.5 | 3.4 | 5 | 1 | 1.1 | 5 | 1 | 0.3 | 1 | 0.7 | 0.2 | 1 |
| 22 | 28May-3Jun2007 | 0.2 | 0.1 | 1 | 6 | 2.0 | 1 | 1.5 | 2.0 | 5 | 1 | 0.6 | 1 | 1 | 0.2 | 1 | 0.7 | 0.1 | 1 |

Table A-21 Planned and Delivered Flow on Weekly Plan in PPP (Wet Season)

| Week | Date | Canal 1L | | | Canal 1L (Km.8) | | | Canal 1L - 1L | | | Canal 2L - 1L | | | Canal 1R - 1L | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Planned | Delivered | score | Planned | Delivered | score | Planned | Delivered | score | Planned | Delivered | score | Planned | Delivered | score |
| 1 | 1-3 Nov. 2006 | 1.5 | 2.42 | 5 | 0.3 | 1.43 | 5 | 1.0 | 0.43 | 1 | 0.1 | 0.16 | 5 | 0.1 | 0.40 | 5 |
| 2 | 4-10 Nov. 2006 | 1.5 | 2.14 | 5 | 0.3 | 1.08 | 5 | 1.0 | 0.45 | 1 | 0.1 | 0.20 | 5 | 0.1 | 0.41 | 5 |
| 3 | 11-17 Nov. 2006 | 1.5 | 1.92 | 5 | 0.3 | 0.81 | 5 | 1.0 | 0.44 | 1 | 0.1 | 0.30 | 5 | 0.1 | 0.37 | 5 |
| 4 | 18-24 Nov. 2006 | 1.5 | 1.75 | 5 | 0.3 | 0.79 | 5 | 1.0 | 0.40 | 1 | 0.1 | 0.21 | 5 | 0.1 | 0.34 | 5 |
| 5 | 25 Nov. - 1 Dec. 2006 | 2.0 | 2.71 | 5 | 0.7 | 1.58 | 5 | 1.0 | 0.48 | 1 | 0.2 | 0.31 | 5 | 0.1 | 0.33 | 5 |
| 6 | 2-8 Dec. 2006 | 2.0 | 3.50 | 5 | 0.6 | 2.44 | 5 | 1.0 | 0.56 | 1 | 0.2 | 0.21 | 5 | 0.2 | 0.28 | 5 |
| 7 | 9-15 Dec. 2006 | 2.0 | 5.18 | 5 | 0.6 | 3.92 | 5 | 1.0 | 0.69 | 1 | 0.2 | 0.29 | 5 | 0.2 | 0.28 | 5 |
| 8 | 16-22 Dec. 2006 | 2.0 | 4.31 | 5 | 0.6 | 3.14 | 5 | 1.0 | 0.90 | 4 | 0.2 | 0.16 | 3 | 0.2 | 0.12 | 1 |
| 9 | 23-29 Dec. 2006 | 2.0 | 5.08 | 5 | 0.6 | 3.29 | 5 | 1.0 | 1.23 | 5 | 0.2 | 0.33 | 5 | 0.2 | 0.23 | 5 |
| 10 | 30 Dec. 49-5 Jan.2007 | 2.0 | 7.25 | 5 | 0.6 | 3.65 | 5 | 1.0 | 2.80 | 5 | 0.2 | 0.47 | 5 | 0.2 | 0.33 | 5 |
| 11 | 6-12 Jan.2007 | 3.0 | 6.34 | 5 | 0.4 | 4.15 | 5 | 2.0 | 1.44 | 2 | 0.3 | 0.37 | 5 | 0.3 | 0.37 | 5 |
| 12 | 13-19 Jan.2007 | 3.0 | 5.76 | 5 | 0.4 | 2.34 | 5 | 2.0 | 2.71 | 5 | 0.3 | 0.35 | 5 | 0.3 | 0.35 | 5 |
| 13 | 20-26 Jan.2007 | 3.0 | 4.33 | 5 | 0.4 | 1.98 | 5 | 2.0 | 1.63 | 3 | 0.3 | 0.37 | 5 | 0.3 | 0.35 | 5 |
| 14 | 27 Jan.-2 Feb.2007 | 3.0 | 7.14 | 5 | 0.4 | 2.98 | 5 | 2.0 | 3.35 | 5 | 0.3 | 0.44 | 5 | 0.3 | 0.36 | 5 |
| 15 | 3-9 Feb.2007 | 3.0 | 4.82 | 5 | 0.4 | 2.10 | 5 | 2.0 | 1.93 | 5 | 0.3 | 0.45 | 5 | 0.3 | 0.34 | 5 |
| 16 | 10-16 Feb.2007 | 2.0 | 7.19 | 5 | 0.1 | 3.14 | 5 | 1.5 | 3.22 | 5 | 0.2 | 0.46 | 5 | 0.2 | 0.36 | 5 |
| 17 | 17-23 Feb.2007 | 2.0 | 8.17 | 5 | 0.1 | 5.23 | 5 | 1.5 | 2.05 | 5 | 0.2 | 0.50 | 5 | 0.2 | 0.39 | 5 |
| 18 | 24 Feb.-2 Mar. 2007 | 2.0 | 9.68 | 5 | 0.1 | 5.58 | 5 | 1.5 | 3.32 | 5 | 0.2 | 0.41 | 5 | 0.2 | 0.37 | 5 |
| 19 | 3-9 Mar. 2007 | 2.0 | 8.63 | 5 | 0.1 | 5.68 | 5 | 1.5 | 2.16 | 5 | 0.2 | 0.41 | 5 | 0.2 | 0.37 | 5 |
| 20 | 10-16 Mar. 2007 | 2.0 | 10.05 | 5 | 0.1 | 5.90 | 5 | 1.5 | 3.28 | 5 | 0.2 | 0.47 | 5 | 0.2 | 0.39 | 5 |
| 21 | 17-23 Mar. 2007 | 2.0 | 7.89 | 5 | 0.1 | 5.59 | 5 | 1.5 | 1.76 | 5 | 0.2 | 0.21 | 5 | 0.2 | 0.34 | 5 |
| 22 | 24-30 Mar.2007 | 2.0 | 6.94 | 5 | 0.2 | 3.51 | 5 | 1.5 | 2.84 | 5 | 0.2 | 0.33 | 5 | 0.1 | 0.26 | 5 |
| 23 | 31 Mar.- 6 Apr.2007 | 2.0 | 6.31 | 5 | 0.3 | 3.71 | 5 | 1.5 | 1.90 | 5 | 0.1 | 0.35 | 5 | 0.1 | 0.36 | 5 |
| 24 | 7-13 Apr. 2007 | 2.0 | 8.16 | 5 | 0.8 | 4.69 | 5 | 1.0 | 2.51 | 5 | 0.1 | 0.48 | 5 | 0.1 | 0.48 | 5 |
| 25 | 14-20 Apr. 2007 | 2.0 | 7.83 | 5 | 1.3 | 5.75 | 5 | 0.5 | 1.12 | 5 | 0.1 | 0.40 | 5 | 0.1 | 0.55 | 5 |
| 26 | 21-27 Apr.2007 | 1.0 | 9.42 | 5 | 0.3 | 6.70 | 5 | 0.5 | 1.90 | 5 | 0.1 | 0.46 | 5 | 0.1 | 0.35 | 5 |
| 27 | 28-30 Apr. 2007 | 1.0 | 4.50 | 5 | 0.4 | 3.62 | 5 | 0.4 | 0.57 | 5 | 0.1 | 0.19 | 5 | 0.1 | 0.12 | 5 |

Table A-22 Planned and Delivered Flow on Weekly Plan in PPP (Dry Season)

| Week | Date | Canal 1L | | | Canal 1L (Km.8) | | | Canal 1L - 1L | | | Canal 2L - 1L | | | Canal 1R - 1L | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Planned | Delivered | score | Planned | Delivered | score | Planned | Delivered | score | Planned | Delivered | score | Planned | Delivered | score |
| 1 | 1-7 Jun 2006 | 2.5 | 5.84 | 5 | 0.8 | 3.24 | 5 | 1.5 | 2.01 | 5 | 0.1 | 0.17 | 5 | 0.1 | 0.41 | 5 |
| 2 | 8-14 Jun 2006 | 2.5 | 5.95 | 5 | 0.8 | 3.30 | 5 | 1.5 | 1.91 | 5 | 0.1 | 0.35 | 5 | 0.1 | 0.40 | 5 |
| 3 | 15-21 Jun 2006 | 2.5 | 6.24 | 5 | 0.8 | 2.93 | 5 | 1.5 | 2.53 | 5 | 0.1 | 0.39 | 5 | 0.1 | 0.40 | 5 |
| 4 | 22-28 Jun 2006 | 2.5 | 3.91 | 5 | 0.8 | 1.76 | 5 | 1.5 | 1.54 | 5 | 0.1 | 0.20 | 5 | 0.1 | 0.41 | 5 |
| 5 | 29 Jun - 5 July 2006 | 2.5 | 4.57 | 5 | 0.8 | 1.55 | 5 | 1.5 | 2.19 | 5 | 0.1 | 0.44 | 5 | 0.1 | 0.39 | 5 |
| 6 | 6-12 July 2006 | 2.5 | 4.54 | 5 | 0.8 | 1.50 | 5 | 1.5 | 2.18 | 5 | 0.1 | 0.49 | 5 | 0.1 | 0.38 | 5 |
| 7 | 13-19 July 2006 | 2.5 | 4.84 | 5 | 0.8 | 1.62 | 5 | 1.5 | 2.51 | 5 | 0.1 | 0.30 | 5 | 0.1 | 0.41 | 5 |
| 8 | 20-26 July 2006 | 2.5 | 3.84 | 5 | 0.8 | 1.61 | 5 | 1.5 | 1.63 | 5 | 0.1 | 0.19 | 5 | 0.1 | 0.41 | 5 |
| 9 | 27 July - 2 Aug. 2006 | 2.5 | 4.30 | 5 | 0.8 | 1.49 | 5 | 1.5 | 1.98 | 5 | 0.1 | 0.42 | 5 | 0.1 | 0.40 | 5 |
| 10 | 3-9 Aug. 2006 | 2.0 | 5.10 | 5 | 0.8 | 1.40 | 5 | 1.0 | 2.90 | 5 | 0.1 | 0.42 | 5 | 0.1 | 0.39 | 5 |
| 11 | 10-16 Aug. 2006 | 2.0 | 4.23 | 5 | 0.8 | 1.50 | 5 | 1.0 | 1.84 | 5 | 0.1 | 0.49 | 5 | 0.1 | 0.40 | 5 |
| 12 | 17-23 Aug. 2006 | 2.0 | 4.93 | 5 | 0.8 | 1.53 | 5 | 1.0 | 2.59 | 5 | 0.1 | 0.41 | 5 | 0.1 | 0.39 | 5 |
| 13 | 24-30 Aug. 2006 | 2.0 | 4.10 | 5 | 0.8 | 1.47 | 5 | 1.0 | 1.83 | 5 | 0.1 | 0.39 | 5 | 0.1 | 0.41 | 5 |
| 14 | 31 Aug.-6 Sep. 2006 | 2.0 | 4.11 | 5 | 0.8 | 1.63 | 5 | 1.0 | 1.72 | 5 | 0.1 | 0.34 | 5 | 0.1 | 0.42 | 5 |
| 15 | 7-13 Sep. 2006 | 2.0 | 3.46 | 5 | 0.8 | 1.60 | 5 | 1.0 | 1.03 | 5 | 0.1 | 0.41 | 5 | 0.1 | 0.41 | 5 |
| 16 | 14-20 Sep.2006 | 2.0 | 2.81 | 5 | 0.8 | 1.54 | 5 | 1.0 | 0.62 | 1 | 0.1 | 0.25 | 5 | 0.1 | 0.41 | 5 |
| 17 | 21-27 Sep. 2006 | 2.0 | 8.11 | 5 | 0.8 | 6.59 | 5 | 1.0 | 0.81 | 3 | 0.1 | 0.26 | 5 | 0.1 | 0.45 | 5 |
| 18 | 28 Sep.- 4 Oct. 2006 | 1.5 | 16.23 | 5 | 0.3 | 14.54 | 5 | 1.0 | 0.99 | 5 | 0.1 | 0.25 | 5 | 0.1 | 0.45 | 5 |
| 19 | 5-11 Oct. 2006 | 1.5 | 18.80 | 5 | 0.3 | 16.88 | 5 | 1.0 | 1.03 | 5 | 0.1 | 0.34 | 5 | 0.1 | 0.55 | 5 |
| 20 | 12-18 Oct. 2006 | 1.5 | 17.04 | 5 | 0.3 | 15.18 | 5 | 1.0 | 0.56 | 1 | 0.1 | 0.25 | 5 | 0.1 | 0.46 | 5 |
| 21 | 19-25 Oct. 2006 | 1.5 | 18.79 | 5 | 0.3 | 16.26 | 5 | 1.0 | 1.23 | 5 | 0.1 | 0.54 | 5 | 0.1 | 0.56 | 5 |
| 22 | 26-31 Oct. 2006 | 1.5 | 8.22 | 5 | 0.3 | 6.13 | 5 | 1.0 | 0.79 | 1 | 0.1 | 0.08 | 3 | 0.1 | 0.35 | 5 |

Table A-23 Relationship of Canals and Zone Boundaries in KPP

| Water Allocation Section | Canal | Zone | Wet Score | Dry Score |
|---|---|---|---|---|
| 1 | Canal 3L | 1 | 1 | 1 |
| 1 | Canal 4L | 2,3 | 2 | 3 |
| 1 | Canal 1L-4L | 2,4 | 5 | 5 |
| 1 | Canal 4L(Km.3+100) | 2 | 1 | 3 |
| 1 | Canal 1L - 5L | 5,7 | 5 | 5 |
| 1 | Canal 1R- 1L - 5L (Km.2+244) | 6,7,8 | 5 | 5 |
| 2 | Canal 1R-1L-5L(km.11+714) | 9,11,13 | 5 | 5 |
| 2 | Canal 1R-1L-5L(km.29+234) | 15 | 4 | 4 |
| 2 | Canal 1R-1L-5L(km.32+620) | 24 | 5 | 3 |
| 2 | Canal 1R-1L-5L(km.36+976) | 25,27 | 5 | 5 |
| 2 | Canal 1R-1L-5L(km.42+100) | 27 | 4 | 4 |
| 2 | Canal 3L-1R-1L-5L | 9 | 4 | 1 |
| 2 | Canal 4L-1R-1L-5L | 11 | 3 | 1 |
| 2 | Canal 5L-1R-1L-5L | 13 | 2 | 1 |
| 2 | Canal 6L-1R-1L-5L | 13 | 4 | 2 |
| 2 | Canal 7L-1R-1L-5L | 15 | 1 | 1 |
| 2 | Canal 8L-1R-1L-5L | 25,26 | 3 | 1 |
| 3 | Canal 2R-1R-1L-5L | 12,14,18 | 2 | 3 |
| 3 | Canal 2R-1R-1L-5L (Km.15+000) | 16,17 | 2 | 4 |
| 3 | Canal 2R-2R-1R-1L-5L | 12 | 4 | 5 |
| 3 | Canal 3R-2R-1R-1L-5L | 14 | 1 | 4 |
| 3 | Canal 4R-2R-1R-1L-5L | 18,20 | 5 | 5 |
| 3 | Canal 5R-2R-1R-1L-5L | 17 | 5 | 5 |
| 3 | Canal 2L-5L | 10 | 3 | 4 |
| 3 | Canal 2L-5L(Km.10+920) | 19 | 5 | 5 |
| 3 | Canal 2L-5L(Km.18+210) | 22 | 5 | 5 |
| 3 | Canal 2L-5L(Km.26+900) | 23 | 2 | 2 |
| 3 | Canal 1L-2L-5L | 19,21 | 2 | 5 |

Table A-24 Relationship of Canals and Zone Boundaries in PPP

| Water Allocation Section | Canal | Zone | Wet Score | Dry Score |
|---|---|---|---|---|
| 1 | Canal 1L | 2,4 | 5 | 5 |
| 1 | Canal 1L(Km.8) | 5,6,8,9,10 | 4 | 3 |
| 1 | Canal 1L-1L | 1,3,6,7 | 3 | 2 |
| 1 | Canal 2L-1L | 2,3 | 4 | 3 |
| 1 | Canal 1R -1L | 4 | 5 | 4 |

Table A-25 Type of Crops Planted of Each Zone in KPP (Wet Season)

| Zone | Type of crop planted-(Ha) | | | | | | Shrimp farm and fish pond | Total |
|---|---|---|---|---|---|---|---|---|
| | Rice | Sugarcane | Farm crop | Vegetable | Fruit tree | Perennial plant | | |
| 1 | 458 | 84 | 6 | 21 | 24 | - | 6 | 599 |
| 2 | 408 | 380 | 39 | 378 | 125 | - | 6 | 1,336 |
| 3 | 288 | 487 | - | 428 | 27 | - | 3 | 1,233 |
| 4 | 405 | 835 | - | 193 | 6 | - | 9 | 1,447 |
| 5 | 293 | 972 | - | 168 | 69 | - | 2 | 1,504 |
| 6 | 440 | 669 | 23 | 64 | 33 | - | - | 1,229 |
| 7 | 188 | 857 | 5 | 63 | 47 | 4 | 1 | 1,164 |
| 8 | 53 | 1,528 | 34 | 15 | 48 | - | 11 | 1,690 |
| 9 | 326 | 671 | 12 | 60 | 117 | 98 | 2 | 1,285 |
| 10 | 200 | 1,480 | 391 | 51 | 41 | - | - | 2,163 |
| 11 | 630 | 1,230 | 8 | 80 | 62 | 36 | 5 | 2,051 |
| 12 | 254 | 1,439 | 37 | 103 | 80 | 32 | 8 | 1,952 |
| 13 | 973 | 682 | 96 | 23 | 20 | - | 111 | 1,904 |
| 14 | 144 | 655 | 41 | 11 | 19 | - | 6 | 876 |
| 15 | 934 | 92 | 431 | 13 | - | - | 90 | 1,560 |
| 16 | 365 | 165 | 146 | 49 | 34 | - | 93 | 852 |
| 17 | 706 | 7 | 23 | 14 | 24 | - | 33 | 807 |
| 18 | 448 | 288 | 56 | 72 | - | - | 30 | 895 |
| 19 | 392 | 898 | 124 | 93 | 24 | - | 21 | 1,551 |
| 20 | 553 | 193 | 28 | 28 | 50 | - | 8 | 860 |
| 21 | 480 | 19 | 51 | 60 | 43 | 27 | 2 | 683 |
| 22 | 448 | 14 | 419 | 54 | 8 | 2 | 52 | 998 |
| 23 | 800 | 11 | 37 | 19 | 16 | - | 3 | 885 |
| 24 | 763 | - | 92 | 18 | 27 | - | 33 | 934 |
| 25 | 1,410 | 51 | 58 | 57 | 8 | - | 17 | 1,601 |
| 26 | 1,718 | - | 369 | - | 81 | - | 6 | 2,175 |
| 27 | 1,108 | - | 92 | 80 | 324 | - | 22 | 1,626 |
| Total | 15,184 | 13,708 | 2,618 | 2,213 | 1,358 | - | 581 | 35,861 |

Table A-26 Type of Crops Planted of Each Zone in KPP (Dry Season)

| Zone | Type of crop planted-(Ha) | | | | | | Shrimp farm and fish pond | Total |
|---|---|---|---|---|---|---|---|---|
| | Rice | Sugarcane | Farm crop | Vegetable | Fruit tree | Perennial plant | | |
| 1 | 567 | 117 | 16 | 14 | 14 | - | 7 | 736 |
| 2 | 393 | 331 | - | 432 | 113 | 5 | 5 | 1,280 |
| 3 | 323 | 367 | - | 547 | 8 | 17 | 2 | 1,263 |
| 4 | 88 | 340 | 13.6 | 208 | 3 | 1 | 5 | 660 |
| 5 | 292 | 616 | - | 505 | 7 | 62 | 12 | 1,494 |
| 6 | 262 | 466 | 42 | 130 | 9 | - | 31.04 | 939 |
| 7 | 189 | 854 | 4 | 69 | 4 | 86 | 6 | 1,212 |
| 8 | 38 | 1,352 | - | 82 | 26 | 6 | 21 | 1,527 |
| 9 | 171 | 232 | - | 263 | 87 | 98 | 6 | 856 |
| 10 | 152 | 1,347 | 67 | 361 | 40 | - | 26.24 | 1,994 |
| 11 | 483 | 309 | 61 | 524 | 52 | 2 | 21 | 1,452 |
| 12 | 200 | 1,200 | 112 | 330 | 23 | 35 | 19 | 1,919 |
| 13 | 796 | 1,008 | 89 | 32 | 47 | 15 | 83 | 2,071 |
| 14 | 225 | 550 | 34 | 76 | 11 | - | 39 | 936 |
| 15 | 810 | 375 | 102 | 85 | 8.64 | 90 | 50 | 1,521 |
| 16 | 207 | 22 | 24 | 107 | 125 | - | 250 | 736 |
| 17 | 747 | - | 3 | 23 | 20 | - | 70 | 862 |
| 18 | 158 | 101 | 143 | 267 | 24 | 8 | 187 | 888 |
| 19 | 144 | 272 | 285 | 352 | 35 | 13 | 119 | 1,220 |
| 20 | 659 | 44 | 93 | 98 | 50 | - | 36 | 980 |
| 21 | 694 | 13 | 41 | 140 | 82 | - | 23 | 992 |
| 22 | 606 | 2 | 88 | 584 | 8 | 1 | 174 | 1,464 |
| 23 | 1,091 | 10 | 9 | 35 | 12 | - | 17 | 1,174 |
| 24 | 1,116 | - | 201 | 262 | 119 | 2 | 266 | 1,967 |
| 25 | 1,275 | - | 17 | 39 | 20 | - | 28 | 1,379 |
| 26 | 1,471 | - | 59 | 69.6 | 5 | 6 | 137 | 1,748 |
| 27 | 1,992 | - | 34 | 46 | 318 | - | 17 | 2,407 |
| Total | 15,148 | 9,930 | 1,537 | 5,680 | 1,272 | 448 | 1,658 | 35,675 |

Table A-27 Type of Crops Planted of Each Zone in PPP (Wet Season)

| Zone | Type of crop planted-(Ha) | | | | Shrimp farm and fish pond | Total |
|---|---|---|---|---|---|---|
| | Rice | Farm crop | Vegetable | Fruit tree | | |
| 1 | 539 | - | - | 45 | - | 584 |
| 2 | 1,419 | - | - | 57 | 11 | 1,487 |
| 3 | 913 | - | - | 56 | 1 | 970 |
| 4 | 522 | - | - | 41 | - | 563 |
| 5 | 808 | - | - | 65 | 3 | 876 |
| 6 | 682 | - | - | 54 | 10 | 746 |
| 7 | 777 | - | - | 114 | 13 | 904 |
| 8 | 694 | - | - | 27 | 83 | 804 |
| 9 | 760 | - | - | 44 | - | 804 |
| 10 | 481 | - | - | - | 16 | 497 |
| 11 | 663 | - | - | 4 | 53 | 720 |
| Total | 8,258 | - | - | 507 | 190 | 8,955 |

Table A-28 Type of Crops Planted of Each Zone in PPP (Dry Season)

| Zone | Type of crop planted-(Ha) | | | | Shrimp farm and fish pond | Total |
|---|---|---|---|---|---|---|
| | Rice | Farm crop | Vegetable | Fruit tree | | |
| 1 | 930 | 18 | - | 45 | - | 993 |
| 2 | 1,462 | 164 | - | 57 | 11 | 1,694 |
| 3 | 1,597 | 29 | - | 56 | 1 | 1,683 |
| 4 | 841 | - | - | 41 | - | 882 |
| 5 | 1,569 | 3 | - | 65 | 3 | 1,640 |
| 6 | 1,195 | - | - | 54 | 10 | 1,259 |
| 7 | 1,306 | - | - | 114 | 13 | 1,433 |
| 8 | 1,170 | - | - | 27 | 83 | 1,280 |
| 9 | 1,498 | - | - | 44 | - | 1,542 |
| 10 | 798 | - | - | - | 16 | 814 |
| 11 | 841 | - | - | 4 | 53 | 898 |
| Total | 13,207 | 214 | - | 507 | 190 | 14,118 |

Table A-29 Average of Reference Evapotranspiration in KPP

| Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Avg.$T_{Max}$(˚C) | 31.43 | 33.30 | 34.84 | 36.05 | 34.81 | 34.24 | 33.52 | 33.18 | 32.79 | 31.4 | 30.71 | 29.76 |
| Avg.$T_{Min}$ (˚C) | 19.03 | 21.02 | 23.59 | 24.94 | 25.09 | 24.85 | 24.57 | 24.47 | 24.21 | 23.53 | 21.48 | 18.98 |
| Avg. Sunshine (hr.) | 7.63 | 8.48 | 7.99 | 8.50 | 6.84 | 5.51 | 4.65 | 4.36 | 5.05 | 6.21 | 7.19 | 7.31 |
| Avg. Rh (%) | 69.07 | 67.67 | 68.40 | 68.53 | 72.33 | 73.73 | 74.80 | 75.07 | 76.20 | 76.87 | 73.20 | 70.46 |
| Avg. Wind (km/hr) | 3.33 | 4.44 | 5.37 | 5.56 | 5.00 | 5.37 | 5.46 | 5.56 | 3.70 | 3.43 | 4.82 | 4.63 |
| ETo (mm/day) | 3.63 | 4.56 | 5.62 | 5.67 | 4.94 | 4.52 | 4.25 | 4.17 | 3.96 | 3.83 | 3.79 | 3.53 |
| Rain (mm/month) | 2.8 | 4.2 | 29.9 | 41.9 | 130.7 | 111.2 | 94.9 | 107.4 | 215.3 | 173.8 | 29.4 | 6.1 |
| Pe (mm/month) | 0.0 | 0.0 | 9.9 | 16.0 | 76.5 | 62.8 | 51.4 | 60.2 | 135.7 | 106.7 | 9.7 | 0.0 |

Table A-30 Average of Reference Evapotranspiration in PPP

| Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Avg.$T_{Max}$(˚C) | 31.82 | 33.84 | 35.63 | 36.74 | 35.45 | 34.48 | 33.87 | 33.56 | 32.96 | 31.92 | 31.07 | 30.33 |
| Avg.$T_{Min}$ (˚C) | 19.26 | 21.19 | 23.46 | 25.07 | 25.31 | 25.09 | 24.73 | 24.58 | 24.32 | 23.92 | 21.96 | 19.25 |
| Avg. Sunshine (hr.) | 7.67 | 8.27 | 7.55 | 8.43 | 6.73 | 4.99 | 4.16 | 4.00 | 5.07 | 6.58 | 7.83 | 8.04 |
| Avg. Rh (%) | 68.54 | 68.43 | 68.07 | 67.50 | 71.04 | 71.00 | 72.61 | 73.25 | 76.57 | 77.11 | 72.93 | 68.69 |
| Avg. Wind (km/hr) | 3.89 | 5.19 | 6.48 | 6.67 | 5.93 | 6.67 | 6.48 | 6.48 | 4.07 | 4.26 | 5.74 | 5.37 |
| ETo (mm/day) | 3.77 | 4.69 | 5.36 | 5.95 | 5.16 | 4.7 | 4.37 | 3.35 | 4.01 | 4.02 | 4.05 | 3.81 |
| Rain (mm/month) | 2.1 | 10.2 | 20.0 | 55.5 | 121.1 | 98.0 | 92.7 | 101.4 | 244.8 | 172.4 | 33.4 | 4.0 |
| Pe (mm/month) | 0.0 | 0.1 | 5.0 | 23.8 | 69.8 | 53.6 | 49.9 | 56.0 | 156.4 | 105.7 | 11.7 | 0.0 |

Table A-31 Crop Coefficient (Kc) Data for Different Crops on Week

| Week | Rice (HYN) | Baby corn | Onion | Shirm farm or fish pond |
|---|---|---|---|---|
| 1 | 1.03 | 0.65 | 0.75 | 1 |
| 2 | 1.07 | 0.68 | 0.76 | 1 |
| 3 | 1.12 | 0.84 | 0.80 | 1 |
| 4 | 1.29 | 0.99 | 0.88 | 1 |
| 5 | 1.38 | 1.16 | 1.01 | 1 |
| 6 | 1.45 | 1.22 | 1.12 | 1 |
| 7 | 1.50 | 1.21 | 1.21 | 1 |
| 8 | 1.48 | 1.15 | 1.32 | 1 |
| 9 | 1.42 | 0.96 | 1.38 | 1 |
| 10 | 1.34 | 0.72 | 1.41 | 1 |
| 11 | 1.23 | 0.61 | 1.40 | 1 |
| 12 | 0.94 | 0.65 | 1.37 | 1 |
| 13 | 0.86 | 0.68 | 1.33 | 1 |
| 14 | | 0.84 | 1.29 | 1 |
| 15 | | | 1.22 | 1 |
| Average | 1.24 | 0.93 | 1.15 | 1 |

Table A-32 Crop Coefficient (Kc) Data for Different Crops on Month

| Month | Pomelo | Mango | Sugarcane | Asparagus |
|---|---|---|---|---|
| 1 | 1.74 | 2.10 | 0.65 | 0.68 |
| 2 | 1.62 | 2.46 | 0.86 | 1.10 |
| 3 | 1.45 | 2.53 | 1.13 | 1.42 |
| 4 | 1.12 | 2.28 | 1.35 | 1.48 |
| 5 | 1.02 | 2.29 | 1.56 | 1.29 |
| 6 | 1.13 | 2.50 | 1.29 | 1.08 |
| 7 | 1.97 | 1.90 | 1.20 | 0.83 |
| 8 | 2.44 | 1.69 | 0.93 | 0.66 |
| 9 | 2.36 | 1.61 | 0.63 | 0.55 |
| 10 | 1.97 | 1.27 | 0.52 | 0.61 |
| 11 | 1.96 | 1.24 | | 0.76 |
| 12 | 1.90 | 1.19 | | 0.74 |
| Average | 1.72 | 1.92 | 1.01 | 0.93 |

Table A-33 Field Application Ratio on Week in KPP (Wet Season)

| Week | Date | Canal 3L | | | | Canal 1L-4L | | | | Canal 4L | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score |
| 7 | 7-13 Aug 2006 | 229,824 | 237,119 | 1.0 | 5 | 533,088 | 591,294 | 0.90 | 5 | 701,568 | 677,877 | 1.0 | 5 |
| 8 | 14-20 Aug 2006 | - | 242,464 | - | - | 351,648 | 599,024 | 0.59 | 1 | 683,424 | 683,408 | 1.0 | 5 |
| 9 | 21-27 Aug 2006 | - | 249,145 | - | - | 639,360 | 608,687 | 1.05 | 5 | 1,057,536 | 690,323 | 1.5 | 5 |
| 10 | 28Aug -3Sep2006 | 286,848 | 271,860 | 1.1 | 5 | 531,360 | 641,542 | 0.83 | 4 | 958,176 | 713,832 | 1.3 | 5 |
| 11 | 4-10Sep2006 | 357,696 | 269,910 | 1.3 | 5 | 488,160 | 612,499 | 0.80 | 3 | 1,002,240 | 674,829 | 1.5 | 5 |
| 12 | 11-17Sep2006 | 364,608 | 278,793 | 1.3 | 5 | 483,840 | 625,346 | 0.77 | 3 | 889,920 | 684,021 | 1.3 | 5 |
| 13 | 18-24Sep2006 | 203,040 | 285,137 | 0.7 | 1 | 598,752 | 634,523 | 0.94 | 5 | 768,096 | 690,588 | 1.1 | 5 |
| 14 | 25Sep-1Oct2006 | 170,208 | 282,600 | 0.6 | 1 | 509,760 | 630,852 | 0.81 | 4 | 917,568 | 687,961 | 1.3 | 5 |
| 15 | 2-8Oct2006 | 311,904 | 261,445 | 1.2 | 5 | 536,544 | 553,165 | 0.97 | 5 | 1,220,832 | 608,961 | 2.0 | 5 |
| 16 | 9-15Oct2006 | 318,816 | 251,626 | 1.3 | 5 | 539,136 | 538,965 | 1.00 | 5 | 1,061,856 | 598,800 | 1.8 | 5 |
| 17 | 16-22Oct2006 | 325,728 | 238,127 | 1.4 | 5 | 526,176 | 519,439 | 1.01 | 5 | 1,057,536 | 584,828 | 1.8 | 5 |
| 18 | 23-29Oct2006 | 360,288 | 202,536 | 1.8 | 5 | 707,616 | 467,963 | 1.51 | 5 | 1,298,592 | 547,994 | 2.4 | 5 |
| 19 | 30Oct-5Nov2006 | 343,008 | 184,509 | 1.9 | 5 | 848,448 | 396,303 | 2.14 | 5 | 1,446,336 | 477,290 | 3.0 | 5 |
| 20 | 6-12Nov2006 | 354,240 | 184,509 | 1.9 | 5 | 956,448 | 396,303 | 2.41 | 5 | 1,392,768 | 477,290 | 2.9 | 5 |
| 21 | 13-19Nov2006 | 308,448 | 184,509 | 1.7 | 5 | 834,624 | 396,303 | 2.11 | 5 | 1,233,792 | 477,290 | 2.6 | 5 |
| 22 | 20-26Nov2006 | 304,992 | 184,509 | 1.7 | 5 | - | 396,303 | - | - | 851,040 | 477,290 | 1.8 | 5 |

Table A-33 (Cont.)

| Week | Date | Canal 4L(Km.3+100) | | | | Canal 1L - 5L | | | | Canal 1R- 1L - 5L (Km.2+244) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score |
| 7 | 7-13 Aug 2006 | 350,784 | 277,367 | 1.3 | 5 | 6,948,288 | 737,808 | 9.4 | 5 | 6,306,336 | 318,478 | 19.8 | 5 |
| 8 | 14-20 Aug 2006 | 240,192 | 279,125 | 0.9 | 4 | 6,564,672 | 741,591 | 8.9 | 5 | 5,941,728 | 320,954 | 18.5 | 5 |
| 9 | 21-27 Aug 2006 | 368,064 | 281,322 | 1.3 | 5 | 6,138,720 | 746,320 | 8.2 | 5 | 5,743,008 | 324,048 | 17.7 | 5 |
| 10 | 28Aug -3Sep2006 | 314,496 | 288,793 | 1.1 | 5 | 5,259,168 | 762,397 | 6.9 | 5 | 4,818,528 | 334,568 | 14.4 | 5 |
| 11 | 4-10Sep2006 | 334,368 | 272,555 | 1.2 | 5 | 5,073,408 | 703,160 | 7.2 | 5 | 4,732,128 | 311,831 | 15.2 | 5 |
| 12 | 11-17Sep2006 | 358,560 | 275,476 | 1.3 | 5 | 3,201,120 | 709,446 | 4.5 | 5 | 2,972,160 | 315,944 | 9.4 | 5 |
| 13 | 18-24Sep2006 | 302,400 | 277,563 | 1.1 | 5 | 2,258,496 | 713,937 | 3.2 | 5 | 2,058,048 | 318,883 | 6.5 | 5 |
| 14 | 25Sep-1Oct2006 | 179,712 | 276,729 | 0.6 | 1 | 3,761,856 | 712,141 | 5.3 | 5 | 3,528,576 | 317,707 | 11.1 | 5 |
| 15 | 2-8Oct2006 | 336,960 | 247,615 | 1.4 | 5 | 4,046,976 | 595,765 | 6.8 | 5 | 3,719,520 | 268,914 | 13.8 | 5 |
| 16 | 9-15Oct2006 | 235,008 | 244,386 | 1.0 | 5 | 4,173,984 | 588,815 | 7.1 | 5 | 3,804,192 | 264,367 | 14.4 | 5 |
| 17 | 16-22Oct2006 | 232,416 | 239,946 | 1.0 | 5 | 4,197,312 | 579,260 | 7.2 | 5 | 3,714,336 | 258,115 | 14.4 | 5 |
| 18 | 23-29Oct2006 | 311,904 | 228,240 | 1.4 | 5 | 5,086,368 | 554,070 | 9.2 | 5 | 4,389,120 | 241,632 | 18.2 | 5 |
| 19 | 30Oct-5Nov2006 | 429,408 | 202,897 | 2.1 | 5 | 5,685,120 | 444,012 | 12.8 | 5 | 5,009,472 | 195,607 | 25.6 | 5 |
| 20 | 6-12Nov2006 | 389,664 | 202,897 | 1.9 | 5 | 5,409,504 | 444,012 | 12.2 | 5 | 4,523,904 | 195,607 | 23.1 | 5 |
| 21 | 13-19Nov2006 | 355,968 | 202,897 | 1.8 | 5 | 5,371,488 | 444,012 | 12.1 | 5 | 4,351,968 | 195,607 | 22.2 | 5 |
| 22 | 20-26Nov2006 | - | 202,897 | - | 0 | 4,332,096 | 444,012 | 9.8 | 5 | 3,246,048 | 195,607 | 16.6 | 5 |

Table A-33 (Cont.)

| Week | Date | Canal 1R-1L-5L(km.11+714) | | | | Canal 1R-1L-5L(km.29+234) | | | | Canal 1R-1L-5L(km.32+620) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score |
| 7 | 7-13 Aug 2006 | 2,981,664 | 710,637 | 4.2 | 5 | 1,530,144 | 421,108 | 3.6 | 5 | 1,378,944 | 259,063 | 5.3 | 5 |
| 8 | 14-20 Aug 2006 | 6,523,200 | 720,086 | 9.1 | 5 | 1,286,496 | 428,394 | 3.0 | 5 | 1,475,712 | 264,440 | 5.6 | 5 |
| 9 | 21-27 Aug 2006 | 6,285,600 | 731,897 | 8.6 | 5 | 1,360,800 | 437,501 | 3.1 | 5 | 1,639,008 | 271,160 | 6.0 | 5 |
| 10 | 28Aug -3Sep2006 | 5,757,696 | 772,056 | 7.5 | 5 | 1,377,216 | 468,466 | 2.9 | 5 | 1,830,816 | 294,011 | 6.2 | 5 |
| 11 | 4-10Sep2006 | 5,745,600 | 740,301 | 7.8 | 5 | 1,191,456 | 459,510 | 2.6 | 5 | 1,796,256 | 293,127 | 6.1 | 5 |
| 12 | 11-17Sep2006 | 5,704,992 | 756,004 | 7.5 | 5 | 1,257,120 | 471,618 | 2.7 | 5 | 1,796,256 | 302,062 | 5.9 | 5 |
| 13 | 18-24Sep2006 | 5,704,992 | 767,221 | 7.4 | 5 | 1,118,880 | 480,267 | 2.3 | 5 | 1,796,256 | 308,445 | 5.8 | 5 |
| 14 | 25Sep-1Oct2006 | 5,319,648 | 762,734 | 7.0 | 5 | 1,182,816 | 476,808 | 2.5 | 5 | 1,794,528 | 305,892 | 5.9 | 5 |
| 15 | 2-8Oct2006 | 5,356,800 | 677,143 | 7.9 | 5 | 1,399,680 | 440,991 | 3.2 | 5 | 1,683,936 | 290,030 | 5.8 | 5 |
| 16 | 9-15Oct2006 | 5,356,800 | 659,786 | 8.1 | 5 | 1,239,840 | 427,608 | 2.9 | 5 | 1,557,792 | 280,154 | 5.6 | 5 |
| 17 | 16-22Oct2006 | 5,356,800 | 635,919 | 8.4 | 5 | 1,233,792 | 409,205 | 3.0 | 5 | 1,354,752 | 266,574 | 5.1 | 5 |
| 18 | 23-29Oct2006 | 5,356,800 | 572,998 | 9.3 | 5 | 1,233,792 | 360,690 | 3.4 | 5 | 1,354,752 | 230,772 | 5.9 | 5 |
| 19 | 30Oct-5Nov2006 | 5,356,800 | 495,394 | 10.8 | 5 | 1,243,296 | 330,865 | 3.8 | 5 | 1,289,952 | 219,093 | 5.9 | 5 |
| 20 | 6-12Nov2006 | 5,356,800 | 495,394 | 10.8 | 5 | 1,231,200 | 330,865 | 3.7 | 5 | 1,261,440 | 219,093 | 5.8 | 5 |
| 21 | 13-19Nov2006 | 5,356,800 | 495,394 | 10.8 | 5 | 448,416 | 330,865 | 1.4 | 5 | 1,149,120 | 219,093 | 5.2 | 5 |
| 22 | 20-26Nov2006 | 5,356,800 | 495,394 | 10.8 | 5 | - | 330,865 | - | - | 164,160 | 219,093 | 0.7 | 2 |

Table A-33 (Cont.)

| Week | Date | Canal 1R-1L-5L(km.36+976) | | | | Canal 1R-1L-5L(km.42+100) | | | | Canal 3L-1R-1L-5L | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score |
| 7 | 7-13 Aug 2006 | 1,007,424 | 514,624 | 2.0 | 5 | 432,000 | 220,966 | 2.0 | 5 | 530,496 | 283,604 | 1.9 | 5 |
| 8 | 14-20 Aug 2006 | 1,029,024 | 527,012 | 2.0 | 5 | 381,888 | 226,618 | 1.7 | 5 | 300,672 | 285,343 | 1.1 | 5 |
| 9 | 21-27 Aug 2006 | 1,118,880 | 542,497 | 2.1 | 5 | 338,688 | 233,682 | 1.4 | 5 | 407,808 | 287,517 | 1.4 | 5 |
| 10 | 28Aug -3Sep2006 | 1,082,592 | 595,145 | 1.8 | 5 | 366,336 | 257,699 | 1.4 | 5 | 128,736 | 294,909 | 0.4 | 1 |
| 11 | 4-10Sep2006 | 889,056 | 595,983 | 1.5 | 5 | 421,632 | 259,356 | 1.6 | 5 | 439,776 | 278,725 | 1.6 | 5 |
| 12 | 11-17Sep2006 | 943,488 | 616,570 | 1.5 | 5 | 473,472 | 268,747 | 1.8 | 5 | 539,136 | 281,616 | 1.9 | 5 |
| 13 | 18-24Sep2006 | 909,792 | 631,275 | 1.4 | 5 | 501,984 | 275,455 | 1.8 | 5 | 495,936 | 283,680 | 1.7 | 5 |
| 14 | 25Sep-1Oct2006 | 830,304 | 625,393 | 1.3 | 5 | 475,200 | 272,772 | 1.7 | 5 | 70,848 | 282,855 | 0.3 | 1 |
| 15 | 2-8Oct2006 | 861,408 | 587,770 | 1.5 | 5 | 412,128 | 257,700 | 1.6 | 5 | 129,600 | 254,753 | 0.5 | 1 |
| 16 | 9-15Oct2006 | 790,560 | 565,014 | 1.4 | 5 | 311,040 | 247,319 | 1.3 | 5 | 104,544 | 251,559 | 0.4 | 1 |
| 17 | 16-22Oct2006 | 752,544 | 533,726 | 1.4 | 5 | 177,120 | 233,046 | 0.8 | 3 | - | 247,166 | - | 0 |
| 18 | 23-29Oct2006 | 762,048 | 451,237 | 1.7 | 5 | - | 195,415 | - | 0 | - | 235,584 | - | 0 |
| 19 | 30Oct-5Nov2006 | 813,888 | 421,121 | 1.9 | 5 | 141,696 | 183,633 | 0.8 | 3 | 277,344 | 211,508 | 1.3 | 5 |
| 20 | 6-12Nov2006 | 857,088 | 421,121 | 2.0 | 5 | 178,848 | 183,633 | 1.0 | 5 | 336,096 | 211,508 | 1.6 | 5 |
| 21 | 13-19Nov2006 | 232,416 | 421,121 | 0.6 | 1 | 181,440 | 183,633 | 1.0 | 5 | 297,216 | 211,508 | 1.4 | 5 |
| 22 | 20-26Nov2006 | - | 421,121 | - | - | 25,920 | 183,633 | 0.1 | 1 | 300,672 | 211,508 | 1.4 | 5 |

Table A-33 (Cont.)

| Week | Date | Canal 5L-1R-1L-5L | | | | Canal 6L-1R-1L-5L | | | | Canal 7L-1R-1L-5L | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score |
| 7 | 7-13 Aug 2006 | 151,200 | 398,904 | 0.4 | 1 | 347,328 | 294,583 | 1.2 | 5 | 78,624 | 125,614 | 0.6 | 1 |
| 8 | 14-20 Aug 2006 | 145,152 | 402,007 | 0.4 | 1 | 356,832 | 299,845 | 1.2 | 5 | 78,624 | 127,598 | 0.6 | 1 |
| 9 | 21-27 Aug 2006 | 126,144 | 405,886 | 0.3 | 1 | 348,192 | 306,424 | 1.1 | 5 | 81,216 | 130,078 | 0.6 | 1 |
| 10 | 28Aug -3Sep2006 | 76,896 | 419,074 | 0.2 | 1 | 352,512 | 328,790 | 1.1 | 5 | 85,536 | 138,510 | 0.6 | 1 |
| 11 | 4-10Sep2006 | 127,008 | 389,104 | 0.3 | 1 | 335,232 | 321,329 | 1.0 | 5 | 78,624 | 136,673 | 0.6 | 1 |
| 12 | 11-17Sep2006 | 130,464 | 394,261 | 0.3 | 1 | 224,640 | 330,075 | 0.7 | 1 | 78,624 | 139,970 | 0.6 | 1 |
| 13 | 18-24Sep2006 | 133,056 | 397,944 | 0.3 | 1 | 163,296 | 336,322 | 0.5 | 1 | 33,696 | 142,325 | 0.2 | 1 |
| 14 | 25Sep-1Oct2006 | 114,048 | 396,471 | 0.3 | 1 | 167,616 | 333,823 | 0.5 | 1 | 12,096 | 141,383 | 0.1 | 1 |
| 15 | 2-8Oct2006 | 114,048 | 331,059 | 0.3 | 1 | 214,272 | 304,022 | 0.7 | 1 | 78,624 | 134,594 | 0.6 | 1 |
| 16 | 9-15Oct2006 | 114,048 | 325,359 | 0.4 | 1 | 20,736 | 294,355 | 0.1 | 1 | 78,624 | 130,949 | 0.6 | 1 |
| 17 | 16-22Oct2006 | 100,224 | 317,521 | 0.3 | 1 | - | 281,063 | - | - | 56,160 | 125,938 | 0.4 | 1 |
| 18 | 23-29Oct2006 | - | 296,858 | - | - | - | 246,020 | - | - | - | 112,727 | - | - |
| 19 | 30Oct-5Nov2006 | 92,448 | 234,492 | 0.4 | 1 | 215,136 | 219,925 | 1.0 | 5 | 54,432 | 108,130 | 0.5 | 1 |
| 20 | 6-12Nov2006 | 118,368 | 234,492 | 0.5 | 1 | 311,904 | 219,925 | 1.4 | 5 | 74,304 | 108,130 | 0.7 | 1 |
| 21 | 13-19Nov2006 | 122,688 | 234,492 | 0.5 | 1 | 317,952 | 219,925 | 1.4 | 5 | 78,624 | 108,130 | 0.7 | 2 |
| 22 | 20-26Nov2006 | 17,280 | 234,492 | 0.1 | 1 | 320,544 | 219,925 | 1.5 | 5 | 78,624 | 108,130 | 0.7 | 2 |

Table A-33 (Cont.)

| Week | Date | Canal 8L-1R-1L-5L | | | | Canal 2R-1R-1L-5L | | | | Canal 2R-1R-1L-5L (Km.15+000) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score |
| 7 | 7-13 Aug 2006 | 285,120 | 644,765 | 0.4 | 1 | 2,195,424 | 583,182 | 3.8 | 5 | 565,056 | 298,920 | 1.9 | 5 |
| 8 | 14-20 Aug 2006 | 332,640 | 662,328 | 0.5 | 1 | 2,432,160 | 586,136 | 4.1 | 5 | 417,312 | 304,142 | 1.4 | 5 |
| 9 | 21-27 Aug 2006 | 332,640 | 684,281 | 0.5 | 1 | 2,027,808 | 589,828 | 3.4 | 5 | 438,048 | 310,669 | 1.4 | 5 |
| 10 | 28Aug -3Sep2006 | 332,640 | 758,922 | 0.4 | 1 | 1,530,144 | 602,380 | 2.5 | 5 | 435,456 | 332,860 | 1.3 | 5 |
| 11 | 4-10Sep2006 | 332,640 | 766,182 | 0.4 | 1 | 1,427,328 | 559,879 | 2.5 | 5 | 324,864 | 329,076 | 1.0 | 5 |
| 12 | 11-17Sep2006 | 332,640 | 795,369 | 0.4 | 1 | 1,620,864 | 564,787 | 2.9 | 5 | 417,312 | 337,753 | 1.2 | 5 |
| 13 | 18-24Sep2006 | 332,640 | 816,217 | 0.4 | 1 | 1,349,568 | 568,293 | 2.4 | 5 | 395,712 | 343,952 | 1.2 | 5 |
| 14 | 25Sep-1Oct2006 | 285,120 | 807,878 | 0.4 | 1 | 1,221,696 | 566,891 | 2.2 | 5 | 402,624 | 341,472 | 1.2 | 5 |
| 15 | 2-8Oct2006 | 237,600 | 762,345 | 0.3 | 1 | 1,002,240 | 487,591 | 2.1 | 5 | 514,944 | 323,035 | 1.6 | 5 |
| 16 | 9-15Oct2006 | 237,600 | 730,084 | 0.3 | 1 | 926,208 | 482,165 | 1.9 | 5 | 389,664 | 313,444 | 1.2 | 5 |
| 17 | 16-22Oct2006 | 237,600 | 685,725 | 0.3 | 1 | 875,232 | 474,705 | 1.8 | 5 | 361,152 | 300,255 | 1.2 | 5 |
| 18 | 23-29Oct2006 | 332,640 | 568,778 | 0.6 | 1 | 1,402,272 | 455,038 | 3.1 | 5 | 298,944 | 265,486 | 1.1 | 5 |
| 19 | 30Oct-5Nov2006 | 332,640 | 532,563 | 0.6 | 2 | 1,923,264 | 381,980 | 5.0 | 5 | 319,680 | 251,980 | 1.3 | 5 |
| 20 | 6-12Nov2006 | 332,640 | 532,563 | 0.6 | 1 | 1,786,752 | 381,980 | 4.7 | 5 | 342,144 | 251,980 | 1.4 | 5 |
| 21 | 13-19Nov2006 | 237,600 | 532,563 | 0.4 | 1 | 2,037,312 | 381,980 | 5.3 | 5 | 288,576 | 251,980 | 1.1 | 5 |
| 22 | 20-26Nov2006 | 237,600 | 532,563 | 0.4 | 1 | 1,705,536 | 381,980 | 4.5 | 5 | 260,064 | 251,980 | 1.0 | 5 |

Table A-33 (Cont.)

| Week | Date | Canal 2R-2R-1R-1L-5L | | | | Canal 3R-2R-1R-1L-5L | | | | Canal 4R-2R-1R-1L-5L | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score |
| 7 | 7-13 Aug 2006 | 155,779 | 113,725 | 1.4 | 5 | 113,184 | 134,684 | 0.8 | 4 | 692,064 | 441,195 | 1.6 | 5 |
| 8 | 14-20 Aug 2006 | 199,584 | 114,502 | 1.7 | 5 | 92,448 | 136,290 | 0.7 | 1 | 635,040 | 448,914 | 1.4 | 5 |
| 9 | 21-27 Aug 2006 | 67,392 | 115,473 | 0.6 | 1 | 46,656 | 138,299 | 0.3 | 1 | 598,752 | 458,563 | 1.3 | 5 |
| 10 | 28Aug -3Sep2006 | 29,376 | 118,776 | 0.2 | 1 | 16,416 | 145,127 | 0.1 | 1 | 559,872 | 491,370 | 1.1 | 5 |
| 11 | 4-10Sep2006 | 134,784 | 110,221 | 1.2 | 5 | 11,232 | 137,947 | 0.1 | 1 | 482,112 | 482,754 | 1.0 | 5 |
| 12 | 11-17Sep2006 | 172,800 | 111,512 | 1.5 | 5 | 20,736 | 140,617 | 0.1 | 1 | 826,848 | 495,582 | 1.7 | 5 |
| 13 | 18-24Sep2006 | 82,944 | 112,435 | 0.7 | 2 | 63,072 | 142,524 | 0.4 | 1 | 784,512 | 504,745 | 1.6 | 5 |
| 14 | 25Sep-1Oct2006 | 63,072 | 112,066 | 0.6 | 1 | 32,832 | 141,761 | 0.2 | 1 | 756,000 | 501,080 | 1.5 | 5 |
| 15 | 2-8Oct2006 | 107,136 | 94,238 | 1.1 | 5 | 10,368 | 123,671 | 0.1 | 1 | 174,528 | 465,075 | 0.4 | 1 |
| 16 | 9-15Oct2006 | 165,024 | 92,810 | 1.8 | 5 | - | 120,719 | - | - | 648,000 | 450,895 | 1.4 | 5 |
| 17 | 16-22Oct2006 | 173,664 | 90,847 | 1.9 | 5 | - | 116,661 | - | - | 668,736 | 431,398 | 1.6 | 5 |
| 18 | 23-29Oct2006 | 176,256 | 85,673 | 2.1 | 5 | 26,784 | 105,963 | 0.3 | 1 | 546,048 | 379,997 | 1.4 | 5 |
| 19 | 30Oct-5Nov2006 | 196,992 | 68,806 | 2.9 | 5 | 56,160 | 89,225 | 0.6 | 1 | 571,968 | 350,407 | 1.6 | 5 |
| 20 | 6-12Nov2006 | 163,296 | 68,806 | 2.4 | 5 | 44,928 | 89,225 | 0.5 | 1 | 571,968 | 350,407 | 1.6 | 5 |
| 21 | 13-19Nov2006 | 177,120 | 68,806 | 2.6 | 5 | 62,208 | 89,225 | 0.7 | 1 | 414,720 | 350,407 | 1.2 | 5 |
| 22 | 20-26Nov2006 | 157,248 | 68,806 | 2.3 | 5 | 20,736 | 89,225 | 0.2 | 1 | 487,296 | 350,407 | 1.4 | 5 |

Table A-33 (Cont.)

| Week | Date | Canal 5R-2R-1R-1L-5L | | | | Canal 2L-5L | | | | Canal 2L-5L(Km.10+920) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score | l. of Water Supplied (r | l. of Water Demand (n | Vs/Vd | Score |
| 7 | 7-13 Aug 2006 | 195,264 | 178,164 | 1.1 | 5 | 3,582,144 | 748,800 | 4.8 | 5 | 2,905,632 | 294,200 | 9.9 | 5 |
| 8 | 14-20 Aug 2006 | 205,632 | 182,720 | 1.1 | 5 | 3,826,656 | 751,135 | 5.1 | 5 | 1,966,464 | 296,250 | 6.6 | 5 |
| 9 | 21-27 Aug 2006 | 190,080 | 188,416 | 1.0 | 5 | 3,589,920 | 754,054 | 4.8 | 5 | 1,813,536 | 298,811 | 6.1 | 5 |
| 10 | 28Aug -3Sep2006 | 241,920 | 207,781 | 1.2 | 5 | 2,845,152 | 763,978 | 3.7 | 5 | 1,952,640 | 307,521 | 6.3 | 5 |
| 11 | 4-10Sep2006 | 114,048 | 209,116 | 0.5 | 1 | 2,569,536 | 697,938 | 3.7 | 5 | 2,229,984 | 290,975 | 7.7 | 5 |
| 12 | 11-17Sep2006 | 148,608 | 216,689 | 0.7 | 1 | 3,061,152 | 701,819 | 4.4 | 5 | 2,187,648 | 294,381 | 7.4 | 5 |
| 13 | 18-24Sep2006 | 113,184 | 222,097 | 0.5 | 1 | 2,524,608 | 704,591 | 3.6 | 5 | 1,788,480 | 296,813 | 6.0 | 5 |
| 14 | 25Sep-1Oct2006 | 122,688 | 219,934 | 0.6 | 1 | 2,267,136 | 703,482 | 3.2 | 5 | 1,674,432 | 295,840 | 5.7 | 5 |
| 15 | 2-8Oct2006 | 132,192 | 207,781 | 0.6 | 1 | 2,543,616 | 580,329 | 4.4 | 5 | 1,672,704 | 265,437 | 6.3 | 5 |
| 16 | 9-15Oct2006 | 136,512 | 199,412 | 0.7 | 1 | 2,898,720 | 576,039 | 5.0 | 5 | 1,264,896 | 261,672 | 4.8 | 5 |
| 17 | 16-22Oct2006 | 120,096 | 187,903 | 0.6 | 1 | 2,672,352 | 570,141 | 4.7 | 5 | 1,130,976 | 256,496 | 4.4 | 5 |
| 18 | 23-29Oct2006 | 117,504 | 157,562 | 0.7 | 2 | 2,160,000 | 554,591 | 3.9 | 5 | 1,159,488 | 242,849 | 4.8 | 5 |
| 19 | 30Oct-5Nov2006 | 93,312 | 148,062 | 0.6 | 1 | 3,391,200 | 437,537 | 7.8 | 5 | 2,064,096 | 216,469 | 9.5 | 5 |
| 20 | 6-12Nov2006 | 75,168 | 148,062 | 0.5 | 1 | 2,807,136 | 437,537 | 6.4 | 5 | 1,331,424 | 216,469 | 6.2 | 5 |
| 21 | 13-19Nov2006 | 75,168 | 148,062 | 0.5 | 1 | 1,290,816 | 437,537 | 3.0 | 5 | 862,272 | 216,469 | 4.0 | 5 |
| 22 | 20-26Nov2006 | 78,624 | 148,062 | 0.5 | 1 | 1,845,504 | 437,537 | 4.2 | 5 | 735,264 | 216,469 | 3.4 | 5 |

## Table A-33 (Cont.)

| Week | Date | Canal 2L-5L(Km.18+210) | | | | Canal 2L-5L(Km.26+900) | | | | Canal 1L-2L-5L | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Vol. of Water Supplied (m | l. of Water Demand (r | Vs/Vd | Score | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score |
| 7 | 7-13 Aug 2006 | 1,045,440 | 328,742 | 3.2 | 5 | 484,704 | 351,263 | 1.4 | 5 | 157,248 | 479,652 | 0.3 | 1 |
| 8 | 14-20 Aug 2006 | 1,435,968 | 333,949 | 4.3 | 5 | 466,560 | 360,604 | 1.3 | 5 | 157,248 | 487,700 | 0.3 | 1 |
| 9 | 21-27 Aug 2006 | 1,463,616 | 340,457 | 4.3 | 5 | 508,896 | 372,280 | 1.4 | 5 | 157,248 | 497,760 | 0.3 | 1 |
| 10 | 28Aug -3Sep2006 | 1,279,584 | 362,585 | 3.5 | 5 | 461,376 | 411,978 | 1.1 | 5 | 167,616 | 531,964 | 0.3 | 1 |
| 11 | 4-10Sep2006 | 1,135,296 | 357,461 | 3.2 | 5 | 209,952 | 415,140 | 0.5 | 1 | 186,624 | 523,002 | 0.4 | 1 |
| 12 | 11-17Sep2006 | 1,034,208 | 366,113 | 2.8 | 5 | 585,792 | 430,664 | 1.4 | 5 | 179,712 | 536,377 | 0.3 | 1 |
| 13 | 18-24Sep2006 | 1,034,208 | 372,294 | 2.8 | 5 | 311,904 | 441,752 | 0.7 | 1 | 157,248 | 545,930 | 0.3 | 1 |
| 14 | 25Sep-1Oct2006 | 1,034,208 | 369,822 | 2.8 | 5 | 342,144 | 437,316 | 0.8 | 3 | 157,248 | 542,109 | 0.3 | 1 |
| 15 | 2-8Oct2006 | 554,688 | 351,037 | 1.6 | 5 | 220,320 | 412,038 | 0.5 | 1 | 160,704 | 506,856 | 0.3 | 1 |
| 16 | 9-15Oct2006 | 626,400 | 341,473 | 1.8 | 5 | 498,528 | 394,880 | 1.3 | 5 | 157,248 | 492,072 | 0.3 | 1 |
| 17 | 16-22Oct2006 | 690,336 | 328,323 | 2.1 | 5 | 408,672 | 371,287 | 1.1 | 5 | 44,928 | 471,745 | 0.1 | 1 |
| 18 | 23-29Oct2006 | 695,520 | 293,653 | 2.4 | 5 | 235,872 | 309,088 | 0.8 | 2 | 309,312 | 418,154 | 0.7 | 2 |
| 19 | 30Oct-5Nov2006 | 663,552 | 280,503 | 2.4 | 5 | 206,496 | 288,866 | 0.7 | 2 | 469,152 | 390,299 | 1.2 | 5 |
| 20 | 6-12Nov2006 | 725,760 | 280,503 | 2.6 | 5 | 408,672 | 288,866 | 1.4 | 5 | 405,216 | 390,299 | 1.0 | 5 |
| 21 | 13-19Nov2006 | 188,352 | 280,503 | 0.7 | 1 | 127,872 | 288,866 | 0.4 | 1 | 405,216 | 390,299 | 1.0 | 5 |
| 22 | 20-26Nov2006 | 200,448 | 280,503 | 0.7 | 2 | 48,384 | 288,866 | 0.2 | 1 | 405,216 | 390,299 | 1.0 | 5 |

## Table A-34 Field Application Ratio on Week in KPP (Dry Season)

| Week | Date | Canal 3L | | | | Canal 1L-4L | | | | Canal 4L | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score |
| 7 | 12-18Feb2007 | 319,680 | 244,835 | 1.3 | 5 | 244,512 | 340,940 | 0.72 | 2 | 746,496 | 573,176 | 1.3 | 5 |
| 8 | 19-25Feb2007 | 340,416 | 250,813 | 1.4 | 5 | 835,488 | 346,274 | 2.41 | 5 | 1,470,528 | 579,225 | 2.5 | 5 |
| 9 | 26Feb-4Mar2007 | 374,976 | 258,284 | 1.5 | 5 | 372,384 | 352,941 | 1.06 | 5 | 1,514,592 | 586,786 | 2.6 | 5 |
| 10 | 5-11Mar2007 | 395,712 | 283,689 | 1.4 | 5 | - | 375,611 | - | - | 1,273,536 | 612,494 | 2.1 | 5 |
| 11 | 12-18Mar2007 | 387,072 | 360,224 | 1.1 | 5 | - | 491,952 | - | - | 937,440 | 789,238 | 1.2 | 5 |
| 12 | 19-25Mar2007 | 325,728 | 373,116 | 0.9 | 4 | - | 503,456 | - | - | 1,271,808 | 802,284 | 1.6 | 5 |
| 13 | 26Mar-1Apr2007 | 398,304 | 382,325 | 1.0 | 5 | 120,960 | 511,673 | 0.24 | 1 | 1,324,512 | 811,603 | 1.6 | 5 |
| 14 | 2-8Apr2007 | 406,944 | 378,642 | 1.1 | 5 | 846,720 | 508,386 | 1.67 | 5 | 1,519,776 | 807,876 | 1.9 | 5 |
| 15 | 9-15Apr2007 | 382,752 | 379,293 | 1.0 | 5 | 846,720 | 542,392 | 1.56 | 5 | 1,262,304 | 850,854 | 1.5 | 5 |
| 16 | 16-22Apr2007 | 298,944 | 364,427 | 0.8 | 3 | 846,720 | 529,127 | 1.60 | 5 | 1,303,776 | 835,811 | 1.6 | 5 |
| 17 | 23-29Apr2007 | 368,928 | 343,988 | 1.1 | 5 | 846,720 | 510,888 | 1.66 | 5 | 1,399,680 | 815,127 | 1.7 | 5 |
| 18 | 30Apr-6May2007 | 133,920 | 290,102 | 0.5 | 1 | 846,720 | 462,803 | 1.83 | 5 | 984,960 | 760,597 | 1.3 | 5 |
| 19 | 7-13May2007 | - | 275,237 | - | - | 846,720 | 449,539 | 1.88 | 5 | 451,008 | 745,554 | 0.6 | 1 |
| 20 | 14-20May2007 | - | 256,064 | - | - | 846,720 | 441,915 | 1.92 | 5 | 73,440 | 709,196 | 0.1 | 1 |
| 21 | 21-27May2007 | 258,336 | 256,064 | 1.0 | 5 | 846,720 | 441,915 | 1.92 | 5 | 825,120 | 709,196 | 1.2 | 5 |
| 22 | 28May-3Jun2007 | 194,400 | 256,064 | 0.8 | 5 | 483,840 | 441,915 | 1.09 | 5 | 712,800 | 709,196 | 1.0 | 5 |

## Table A-34 (Cont.)

| Week | Date | Canal 4L(Km.3+100) | | | | Canal 1L - 5L | | | | Canal 1R- 1L - 5L (Km.2+244) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score |
| 7 | 12-18Feb2007 | 451,008 | 340,726 | 1.3 | 5 | 5,990,976 | 557,566 | 10.7 | 5 | 5,685,984 | 277,258 | 20.5 | 5 |
| 8 | 19-25Feb2007 | 441,504 | 344,853 | 1.3 | 5 | 6,688,224 | 562,520 | 11.9 | 5 | 6,161,184 | 281,032 | 21.9 | 5 |
| 9 | 26Feb-4Mar2007 | 500,256 | 350,011 | 1.4 | 5 | 7,656,768 | 568,713 | 13.5 | 5 | 6,788,448 | 285,748 | 23.8 | 5 |
| 10 | 5-11Mar2007 | 385,344 | 367,549 | 1.0 | 5 | 7,933,248 | 589,767 | 13.5 | 5 | 7,234,272 | 301,784 | 24.0 | 5 |
| 11 | 12-18Mar2007 | 324,000 | 475,306 | 0.7 | 1 | 7,712,928 | 793,940 | 9.7 | 5 | 7,236,000 | 399,415 | 18.1 | 5 |
| 12 | 19-25Mar2007 | 373,248 | 484,206 | 0.8 | 3 | 7,000,992 | 804,625 | 8.7 | 5 | 6,644,160 | 407,553 | 16.3 | 5 |
| 13 | 26Mar-1Apr2007 | 372,384 | 490,563 | 0.8 | 2 | 7,351,776 | 812,257 | 9.1 | 5 | 6,861,024 | 413,366 | 16.6 | 5 |
| 14 | 2-8Apr2007 | 461,376 | 488,020 | 0.9 | 5 | 7,881,408 | 809,204 | 9.7 | 5 | 7,249,824 | 411,041 | 17.6 | 5 |
| 15 | 9-15Apr2007 | 393,120 | 514,943 | 0.8 | 3 | 7,483,968 | 909,167 | 8.2 | 5 | 7,096,896 | 446,872 | 15.9 | 5 |
| 16 | 16-22Apr2007 | 393,120 | 504,680 | 0.8 | 3 | 6,558,624 | 896,847 | 7.3 | 5 | 6,621,696 | 437,488 | 15.1 | 5 |
| 17 | 23-29Apr2007 | 393,120 | 490,570 | 0.8 | 3 | 7,745,760 | 879,907 | 8.8 | 5 | 6,765,984 | 424,586 | 15.9 | 5 |
| 18 | 30Apr-6May2007 | 320,544 | 453,369 | 0.7 | 1 | 4,297,536 | 835,248 | 5.1 | 5 | 3,827,520 | 390,571 | 9.8 | 5 |
| 19 | 7-13May2007 | 320,544 | 443,107 | 0.7 | 2 | 1,824,768 | 822,928 | 2.2 | 5 | 1,206,144 | 381,188 | 3.2 | 5 |
| 20 | 14-20May2007 | 91,584 | 424,681 | 0.2 | 1 | 1,435,968 | 836,892 | 1.7 | 5 | 1,356,480 | 380,339 | 3.6 | 5 |
| 21 | 21-27May2007 | 228,960 | 424,681 | 0.5 | 1 | 4,132,512 | 836,892 | 4.9 | 5 | 3,874,176 | 380,339 | 10.2 | 5 |
| 22 | 28May-3Jun2007 | 183,168 | 424,681 | 0.4 | 1 | 3,308,256 | 836,892 | 4.0 | 5 | 3,007,584 | 380,339 | 7.9 | 5 |

## Table A-34 (Cont.)

| Week | Date | Canal 1R-1L-5L(km.11+714) | | | | Canal 1R-1L-5L(km.29+234) | | | | Canal 1R-1L-5L(km.32+620) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score |
| 7 | 12-18Feb2007 | 3,473,280 | 505,291 | 6.87 | 5 | 1,381,536 | 455,367 | 3.03 | 5 | 984,960 | 347,500 | 2.83 | 5 |
| 8 | 19-25Feb2007 | 4,052,160 | 512,598 | 7.91 | 5 | 1,439,424 | 464,151 | 3.10 | 5 | 1,149,120 | 355,014 | 3.24 | 5 |
| 9 | 26Feb-4Mar2007 | 4,052,160 | 521,732 | 7.77 | 5 | 2,069,280 | 475,132 | 4.36 | 5 | 1,149,120 | 364,406 | 3.15 | 5 |
| 10 | 5-11Mar2007 | 4,052,160 | 552,789 | 7.33 | 5 | 1,927,584 | 512,465 | 3.76 | 5 | 1,149,120 | 396,340 | 2.90 | 5 |
| 11 | 12-18Mar2007 | 4,052,160 | 720,681 | 5.62 | 5 | 2,086,560 | 652,430 | 3.20 | 5 | 1,149,120 | 494,943 | 2.32 | 5 |
| 12 | 19-25Mar2007 | 4,052,160 | 736,442 | 5.50 | 5 | 2,130,624 | 671,376 | 3.17 | 5 | 1,149,120 | 511,149 | 2.25 | 5 |
| 13 | 26Mar-1Apr2007 | 4,052,160 | 747,700 | 5.42 | 5 | 1,811,808 | 684,909 | 2.65 | 5 | 1,149,120 | 522,724 | 2.20 | 5 |
| 14 | 2-8Apr2007 | 4,052,160 | 743,197 | 5.45 | 5 | 1,486,944 | 679,496 | 2.19 | 5 | 1,149,120 | 518,094 | 2.22 | 5 |
| 15 | 9-15Apr2007 | 4,052,160 | 789,588 | 5.13 | 5 | 2,200,608 | 690,145 | 3.19 | 5 | 1,149,120 | 508,140 | 2.26 | 5 |
| 16 | 16-22Apr2007 | 4,052,160 | 771,416 | 5.25 | 5 | 1,874,880 | 668,300 | 2.81 | 5 | 1,149,120 | 489,454 | 2.35 | 5 |
| 17 | 23-29Apr2007 | 4,052,160 | 746,429 | 5.43 | 5 | 1,707,264 | 638,263 | 2.67 | 5 | 1,149,120 | 463,762 | 2.48 | 5 |
| 18 | 30Apr-6May2007 | 4,052,160 | 680,554 | 5.95 | 5 | 1,715,904 | 559,073 | 3.07 | 5 | 1,149,120 | 396,027 | 2.90 | 5 |
| 19 | 7-13May2007 | 4,052,160 | 662,382 | 6.12 | 5 | 1,693,440 | 537,228 | 3.15 | 5 | 1,149,120 | 377,342 | 3.05 | 5 |
| 20 | 14-20May2007 | 4,052,160 | 645,265 | 6.28 | 5 | 1,693,440 | 501,592 | 3.38 | 5 | 1,149,120 | 336,715 | 3.41 | 5 |
| 21 | 21-27May2007 | 4,052,160 | 645,265 | 6.28 | 5 | 1,693,440 | 501,592 | 3.38 | 5 | 1,149,120 | 336,715 | 3.41 | 5 |
| 22 | 28May-3Jun2007 | 2,315,520 | 645,265 | 3.59 | 5 | 967,680 | 501,592 | 1.93 | 5 | 656,640 | 336,715 | 1.95 | 5 |

## Table A-34 (Cont.)

| Week | Date | Canal 1R-1L-5L(km.36+976) | | | | Canal 1R-1L-5L(km.42+100) | | | | Canal 3L-1R-1L-5L | | | | Canal 4L-1R-1L-5L | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score |
| 7 | 12-18Feb2007 | 789,696 | 578,739 | 1.36 | 5 | 299,808 | 386,957 | 0.77 | 3 | 297,216 | 198,587 | 1.50 | 2 | 223,776 | 182,572 | 1.23 | 5 |
| 8 | 19-25Feb2007 | 1,022,112 | 594,743 | 1.72 | 5 | 345,600 | 397,004 | 0.87 | 4 | 346,464 | 199,468 | 1.74 | 5 | 239,328 | 185,853 | 1.29 | 5 |
| 9 | 26Feb-4Mar2007 | 1,279,584 | 614,748 | 2.08 | 5 | 369,792 | 409,563 | 0.90 | 5 | 301,536 | 200,568 | 1.50 | 5 | 329,184 | 189,954 | 1.73 | 5 |
| 10 | 5-11Mar2007 | 1,486,080 | 682,764 | 2.18 | 5 | 398,304 | 452,262 | 0.88 | 4 | 275,616 | 204,310 | 1.35 | 5 | 223,776 | 203,897 | 1.10 | 5 |
| 11 | 12-18Mar2007 | 1,527,552 | 857,046 | 1.78 | 5 | 501,120 | 566,047 | 0.89 | 4 | 256,608 | 259,615 | 0.99 | 5 | 206,496 | 258,245 | 0.80 | 3 |
| 12 | 19-25Mar2007 | 1,496,448 | 891,564 | 1.68 | 5 | 521,856 | 587,717 | 0.89 | 4 | 292,896 | 261,514 | 1.12 | 5 | 163,296 | 265,321 | 0.62 | 1 |
| 13 | 26Mar-1Apr2007 | 1,477,440 | 916,219 | 1.61 | 5 | 427,680 | 603,194 | 0.71 | 1 | 247,968 | 262,871 | 0.94 | 5 | 220,320 | 270,375 | 0.81 | 3 |
| 14 | 2-8Apr2007 | 1,261,440 | 906,357 | 1.39 | 5 | 405,216 | 597,003 | 0.68 | 1 | 191,808 | 262,328 | 0.73 | 2 | 336,096 | 268,353 | 1.25 | 5 |
| 15 | 9-15Apr2007 | 1,359,072 | 886,307 | 1.53 | 5 | 519,264 | 582,841 | 0.89 | 4 | 170,208 | 274,451 | 0.62 | 1 | 67,392 | 271,103 | 0.25 | 1 |
| 16 | 16-22Apr2007 | 927,072 | 846,508 | 1.10 | 5 | 515,808 | 557,856 | 0.92 | 5 | 273,888 | 272,261 | 1.01 | 5 | 158,112 | 262,944 | 0.60 | 1 |
| 17 | 23-29Apr2007 | 1,191,456 | 791,784 | 1.50 | 5 | 368,928 | 523,501 | 0.70 | 1 | 281,664 | 269,251 | 1.05 | 5 | 318,816 | 251,725 | 1.27 | 3 |
| 18 | 30Apr-6May2007 | 1,270,944 | 647,512 | 1.96 | 5 | 165,024 | 432,931 | 0.38 | 1 | 136,512 | 261,313 | 0.52 | 1 | 262,656 | 222,149 | 1.18 | 5 |
| 19 | 7-13May2007 | 522,720 | 607,713 | 0.86 | 4 | - | 407,946 | - | - | 145,152 | 259,124 | 0.56 | 1 | 241,920 | 213,990 | 1.13 | 5 |
| 20 | 14-20May2007 | 631,584 | 549,672 | 1.15 | 5 | - | 366,061 | - | - | 145,152 | 239,571 | 0.61 | 1 | 241,920 | 197,442 | 1.23 | 5 |
| 21 | 21-27May2007 | 673,920 | 549,672 | 1.23 | 5 | - | 366,061 | - | - | 154,656 | 239,571 | 0.65 | 1 | 235,872 | 197,442 | 1.19 | 5 |
| 22 | 28May-3Jun2007 | 824,256 | 549,672 | 1.50 | 5 | - | 366,061 | - | - | 121,824 | 239,571 | 0.51 | 1 | 158,976 | 197,442 | 0.81 | 2 |

## Table A-34 (Cont.)

| Week | Date | Canal 5L-1R-1L-5L | | | | Canal 6L-1R-1L-5L | | | | Canal 7L-1R-1L-5L | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score |
| 7 | 12-18Feb2007 | 77,760 | 168,578 | 0.46 | 1 | 346,464 | 253,038 | 1.37 | 5 | 67,392 | 114,803 | 0.59 | 1 |
| 8 | 19-25Feb2007 | 181,440 | 171,052 | 1.06 | 5 | 410,400 | 257,771 | 1.59 | 5 | 79,488 | 116,358 | 0.68 | 1 |
| 9 | 26Feb-4Mar2007 | 190,080 | 174,145 | 1.09 | 5 | 280,800 | 263,688 | 1.06 | 5 | 84,672 | 118,301 | 0.72 | 2 |
| 10 | 5-11Mar2007 | 214,272 | 184,659 | 1.16 | 5 | 350,784 | 283,805 | 1.24 | 5 | 84,672 | 124,908 | 0.68 | 1 |
| 11 | 12-18Mar2007 | 234,144 | 237,079 | 0.99 | 5 | 399,168 | 363,141 | 1.10 | 5 | 84,672 | 155,283 | 0.55 | 1 |
| 12 | 19-25Mar2007 | 230,688 | 242,415 | 0.95 | 5 | 393,120 | 373,350 | 1.05 | 5 | 84,672 | 158,636 | 0.53 | 1 |
| 13 | 26Mar-1Apr2007 | 193,536 | 246,226 | 0.79 | 3 | 369,792 | 380,642 | 0.97 | 5 | 78,624 | 161,031 | 0.49 | 1 |
| 14 | 2-8Apr2007 | 187,488 | 244,702 | 0.77 | 2 | 372,384 | 377,725 | 0.99 | 5 | 78,624 | 160,073 | 0.49 | 1 |
| 15 | 9-15Apr2007 | 187,488 | 254,086 | 0.74 | 2 | 288,576 | 387,048 | 0.75 | 2 | 78,624 | 158,484 | 0.50 | 1 |
| 16 | 16-22Apr2007 | 187,488 | 247,934 | 0.76 | 2 | 273,024 | 375,276 | 0.73 | 2 | 78,624 | 154,618 | 0.51 | 1 |
| 17 | 23-29Apr2007 | 187,488 | 239,474 | 0.78 | 3 | 280,800 | 359,091 | 0.78 | 3 | 78,624 | 149,302 | 0.53 | 1 |
| 18 | 30Apr-6May2007 | 107,136 | 217,172 | 0.49 | 1 | 258,336 | 316,421 | 0.82 | 3 | 78,624 | 135,287 | 0.58 | 1 |
| 19 | 7-13May2007 | 107,136 | 211,020 | 0.51 | 1 | - | 304,650 | - | - | 78,624 | 131,421 | 0.60 | 1 |
| 20 | 14-20May2007 | 133,920 | 199,916 | 0.67 | 1 | 113,184 | 287,394 | 0.39 | 1 | 78,624 | 116,147 | 0.68 | 1 |
| 21 | 21-27May2007 | 107,136 | 199,916 | 0.54 | 1 | 237,600 | 287,394 | 0.83 | 3 | 78,624 | 116,147 | 0.68 | 1 |
| 22 | 28May-3Jun2007 | 107,136 | 199,916 | 0.54 | 1 | 218,592 | 287,394 | 0.76 | 2 | 44,928 | 116,147 | 0.39 | 1 |

## Table A-34 (Cont.)

| Week | Date | Canal 8L-1R-1L-5L | | | | Canal 2R-1R-1L-5L | | | | Canal 2R-1R-1L-5L (Km.15+000) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score |
| 7 | 12-18Feb2007 | 520,128 | 865,978 | 0.6 | 1 | 1,613,952 | 428,840 | 3.8 | 5 | 639,360 | 330,166 | 1.9 | 5 |
| 8 | 19-25Feb2007 | 520,128 | 889,269 | 0.6 | 1 | 1,998,432 | 431,941 | 4.6 | 5 | 725,760 | 336,168 | 2.2 | 5 |
| 9 | 26Feb-4Mar2007 | 520,128 | 918,383 | 0.6 | 1 | 2,246,400 | 435,817 | 5.2 | 5 | 773,280 | 343,671 | 2.3 | 5 |
| 10 | 5-11Mar2007 | 520,128 | 1,017,369 | 0.5 | 1 | 2,220,480 | 448,997 | 4.9 | 5 | 729,216 | 369,179 | 2.0 | 5 |
| 11 | 12-18Mar2007 | 520,128 | 1,273,925 | 0.4 | 1 | 2,821,824 | 591,668 | 4.8 | 5 | 696,384 | 461,280 | 1.5 | 5 |
| 12 | 19-25Mar2007 | 520,128 | 1,324,159 | 0.4 | 1 | 2,408,832 | 598,356 | 4.0 | 5 | 670,464 | 474,225 | 1.4 | 5 |
| 13 | 26Mar-1Apr2007 | 520,128 | 1,360,040 | 0.4 | 1 | 1,894,752 | 603,134 | 3.1 | 5 | 668,736 | 483,471 | 1.4 | 5 |
| 14 | 2-8Apr2007 | 520,128 | 1,345,687 | 0.4 | 1 | 1,880,064 | 601,223 | 3.1 | 5 | 631,584 | 479,773 | 1.3 | 5 |
| 15 | 9-15Apr2007 | 520,128 | 1,312,515 | 0.4 | 1 | 2,302,560 | 658,625 | 3.5 | 5 | 732,672 | 474,221 | 1.5 | 5 |
| 16 | 16-22Apr2007 | 520,128 | 1,254,594 | 0.4 | 1 | 1,905,984 | 650,913 | 2.9 | 5 | 624,672 | 459,295 | 1.4 | 5 |
| 17 | 23-29Apr2007 | 520,128 | 1,174,953 | 0.4 | 1 | 2,298,240 | 640,309 | 3.6 | 5 | 635,040 | 438,772 | 1.4 | 5 |
| 18 | 30Apr-6May2007 | 520,128 | 964,991 | 0.5 | 1 | 1,689,120 | 612,354 | 2.8 | 5 | 555,552 | 384,665 | 1.4 | 5 |
| 19 | 7-13May2007 | 520,128 | 907,070 | 0.6 | 1 | 1,542,240 | 604,642 | 2.6 | 5 | 215,136 | 369,739 | 0.6 | 1 |
| 20 | 14-20May2007 | 520,128 | 814,947 | 0.6 | 1 | 1,542,240 | 595,121 | 2.6 | 1 | 252,288 | 330,523 | 0.8 | 2 |
| 21 | 21-27May2007 | 371,520 | 814,947 | 0.5 | 1 | 1,336,608 | 595,121 | 2.2 | 5 | 304,992 | 330,523 | 0.9 | 5 |
| 22 | 28May-3Jun2007 | 371,520 | 814,947 | 0.5 | 1 | 1,155,168 | 595,121 | 1.9 | 5 | 242,784 | 330,523 | 0.7 | 2 |

## Table A-34 (Cont.)

| Week | Date | Canal 2R-2R-1R-1L-5L | | | | Canal 3R-2R-1R-1L-5L | | | | Canal 4R-2R-1R-1L-5L | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score |
| 7 | 12-18Feb2007 | 312,768 | 66,523 | 4.7 | 5 | 190,944 | 125,819 | 1.5 | 5 | 423,360 | 491,585 | 0.9 | 4 |
| 8 | 19-25Feb2007 | 330,048 | 67,271 | 4.9 | 5 | 201,312 | 127,474 | 1.6 | 5 | 455,328 | 501,338 | 0.9 | 5 |
| 9 | 26Feb-4Mar2007 | 304,992 | 68,205 | 4.5 | 5 | 260,064 | 129,542 | 2.0 | 5 | 593,568 | 513,529 | 1.2 | 5 |
| 10 | 5-11Mar2007 | 272,160 | 71,383 | 3.8 | 5 | 205,632 | 136,575 | 1.5 | 5 | 673,056 | 554,978 | 1.2 | 5 |
| 11 | 12-18Mar2007 | 272,160 | 93,931 | 2.9 | 5 | 173,664 | 182,513 | 1.0 | 5 | 655,776 | 696,756 | 0.9 | 5 |
| 12 | 19-25Mar2007 | 267,840 | 95,544 | 2.8 | 5 | 130,464 | 186,082 | 0.7 | 1 | 709,344 | 717,791 | 1.0 | 5 |
| 13 | 26Mar-1Apr2007 | 251,424 | 96,696 | 2.6 | 5 | 101,088 | 188,631 | 0.5 | 1 | 795,744 | 732,815 | 1.1 | 5 |
| 14 | 2-8Apr2007 | 263,520 | 96,235 | 2.7 | 5 | 60,480 | 187,612 | 0.3 | 1 | 669,600 | 726,806 | 0.9 | 5 |
| 15 | 9-15Apr2007 | 228,960 | 104,297 | 2.2 | 5 | 60,480 | 206,877 | 0.3 | 1 | 698,976 | 721,489 | 1.0 | 5 |
| 16 | 16-22Apr2007 | 152,064 | 102,437 | 1.5 | 5 | 60,480 | 202,762 | 0.3 | 1 | 636,768 | 697,236 | 0.9 | 5 |
| 17 | 23-29Apr2007 | 157,248 | 99,881 | 1.6 | 5 | 60,480 | 197,104 | 0.3 | 1 | 633,312 | 663,888 | 1.0 | 5 |
| 18 | 30Apr-6May2007 | 157,248 | 93,140 | 1.7 | 5 | 94,176 | 182,187 | 0.5 | 1 | 607,392 | 575,969 | 1.1 | 5 |
| 19 | 7-13May2007 | 157,248 | 91,281 | 1.7 | 5 | 6,912 | 178,072 | 0.0 | 1 | 437,184 | 551,715 | 0.8 | 1 |
| 20 | 14-20May2007 | 157,248 | 90,016 | 1.7 | 5 | - | 180,202 | - | - | 385,344 | 498,986 | 0.8 | 3 |
| 21 | 21-27May2007 | 157,248 | 90,016 | 1.7 | 5 | 345,600 | 180,202 | 1.9 | 5 | 422,496 | 498,986 | 0.8 | 4 |
| 22 | 28May-3Jun2007 | 89,856 | 90,016 | 1.0 | 5 | 328,320 | 180,202 | 1.8 | 5 | 275,616 | 498,986 | 0.6 | 1 |

Table A-34 (Cont.)

| Week | Date | Canal 5R-2R-1R-1L-5L | | | | Canal 2L-5L | | | | Canal 2L-5L(Km.10+920) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score | l. of Water Supplied (m | l. of Water Demand (m | Vs/Vd | Score |
| 7 | 12-18Feb2007 | 211,680 | 202,603 | 1.0 | 5 | 3,458,592 | 419,418 | 8.2 | 5 | 2,132,352 | 206,286 | 10.3 | 5 |
| 8 | 19-25Feb2007 | 222,048 | 207,892 | 1.1 | 5 | 3,873,312 | 421,359 | 9.2 | 5 | 2,273,184 | 207,671 | 10.9 | 5 |
| 9 | 26Feb-4Mar2007 | 284,256 | 214,504 | 1.3 | 5 | 4,220,640 | 423,785 | 10.0 | 5 | 1,908,576 | 209,402 | 9.1 | 5 |
| 10 | 5-11Mar2007 | 193,536 | 236,982 | 0.8 | 3 | 4,459,104 | 432,033 | 10.3 | 5 | 1,594,080 | 215,289 | 7.4 | 5 |
| 11 | 12-18Mar2007 | 199,584 | 296,626 | 0.7 | 1 | 3,779,136 | 603,040 | 6.3 | 5 | 2,019,168 | 275,757 | 7.3 | 5 |
| 12 | 19-25Mar2007 | 171,072 | 308,033 | 0.6 | 1 | 3,324,672 | 607,226 | 5.5 | 5 | 1,829,088 | 278,744 | 6.6 | 5 |
| 13 | 26Mar-1Apr2007 | 145,152 | 316,181 | 0.5 | 1 | 3,317,760 | 610,216 | 5.4 | 5 | 2,096,064 | 280,878 | 7.5 | 5 |
| 14 | 2-8Apr2007 | 145,152 | 312,922 | 0.5 | 1 | 4,253,472 | 609,020 | 7.0 | 5 | 2,569,536 | 280,025 | 9.2 | 5 |
| 15 | 9-15Apr2007 | 145,152 | 305,454 | 0.5 | 1 | 4,262,976 | 722,977 | 5.9 | 5 | 2,541,024 | 294,874 | 8.6 | 5 |
| 16 | 16-22Apr2007 | 145,152 | 292,301 | 0.5 | 1 | 3,908,736 | 718,151 | 5.4 | 5 | 2,370,816 | 291,430 | 8.1 | 5 |
| 17 | 23-29Apr2007 | 145,152 | 274,216 | 0.5 | 1 | 3,779,136 | 711,515 | 5.3 | 5 | 2,300,832 | 286,694 | 8.0 | 5 |
| 18 | 30Apr-6May2007 | 176,256 | 226,537 | 0.8 | 3 | 1,880,064 | 694,020 | 2.7 | 5 | 2,276,640 | 274,207 | 8.3 | 5 |
| 19 | 7-13May2007 | 108,864 | 213,384 | 0.5 | 1 | 1,276,992 | 689,193 | 1.9 | 5 | 2,080,512 | 270,763 | 7.7 | 5 |
| 20 | 14-20May2007 | 81,216 | 191,511 | 0.4 | 1 | 1,592,352 | 728,314 | 2.2 | 5 | 2,080,512 | 254,220 | 8.2 | 5 |
| 21 | 21-27May2007 | 93,312 | 191,511 | 0.5 | 1 | 1,463,616 | 728,314 | 2.0 | 5 | 2,080,512 | 254,220 | 8.2 | 5 |
| 22 | 28May-3Jun2007 | 78,624 | 191,511 | 0.4 | 1 | 1,233,792 | 728,314 | 1.7 | 5 | 1,188,864 | 254,220 | 4.7 | 5 |

Table A-34 (Cont.)

| Week | Date | Canal 2L-5L(Km.18+210) | | | | Canal 2L-5L(Km.26+900) | | | | Canal 1L-2L-5L | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Vol. of Water Supplied (m | l. of Water Demand (m | Vs/Vd | Score | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score | Vol. of Water Supplied ($m^3$) | Vol. of Water Demand ($m^3$) | Vs/Vd | Score |
| 7 | 12-18Feb2007 | 695,520 | 448,143 | 1.6 | 5 | 453,600 | 497,885 | 0.9 | 5 | 508,896 | 544,059 | 0.9 | 5 |
| 8 | 19-25Feb2007 | 1,239,840 | 455,880 | 2.7 | 5 | 667,008 | 511,815 | 1.3 | 5 | 405,216 | 553,981 | 0.7 | 2 |
| 9 | 26Feb-4Mar2007 | 1,239,840 | 465,550 | 2.7 | 5 | 544,320 | 529,228 | 1.0 | 5 | 465,696 | 566,384 | 0.8 | 3 |
| 10 | 5-11Mar2007 | 1,188,000 | 498,430 | 2.4 | 5 | 534,816 | 588,432 | 0.9 | 5 | 405,216 | 608,553 | 0.7 | 1 |
| 11 | 12-18Mar2007 | 835,488 | 621,669 | 1.3 | 5 | 450,144 | 737,789 | 0.6 | 1 | 474,336 | 763,104 | 0.6 | 1 |
| 12 | 19-25Mar2007 | 725,760 | 638,354 | 1.1 | 5 | 348,192 | 767,834 | 0.5 | 1 | 647,136 | 784,504 | 0.8 | 3 |
| 13 | 26Mar-1Apr2007 | 946,080 | 650,273 | 1.5 | 5 | 161,568 | 789,295 | 0.2 | 1 | 525,312 | 799,790 | 0.7 | 1 |
| 14 | 2-8Apr2007 | 1,099,872 | 645,506 | 1.7 | 5 | 250,560 | 780,711 | 0.3 | 1 | 418,176 | 793,676 | 0.5 | 1 |
| 15 | 9-15Apr2007 | 1,239,840 | 637,413 | 1.9 | 5 | 559,008 | 761,589 | 0.7 | 2 | 405,216 | 788,906 | 0.5 | 1 |
| 16 | 16-22Apr2007 | 799,200 | 618,174 | 1.3 | 5 | 455,328 | 726,946 | 0.6 | 1 | 395,712 | 764,231 | 0.5 | 1 |
| 17 | 23-29Apr2007 | 725,760 | 591,720 | 1.2 | 5 | 304,992 | 679,312 | 0.4 | 1 | 405,216 | 730,302 | 0.6 | 1 |
| 18 | 30Apr-6May2007 | 753,408 | 521,978 | 1.4 | 5 | 334,368 | 553,733 | 0.6 | 1 | 405,216 | 640,855 | 0.6 | 1 |
| 19 | 7-13May2007 | 812,160 | 502,739 | 1.6 | 5 | 302,400 | 519,090 | 0.6 | 1 | 67,392 | 616,180 | 0.1 | 1 |
| 20 | 14-20May2007 | 784,512 | 447,503 | 1.8 | 5 | 193,536 | 468,053 | 0.4 | 1 | - | 555,645 | - | - |
| 21 | 21-27May2007 | 652,320 | 447,503 | 1.5 | 5 | 193,536 | 468,053 | 0.4 | 1 | 134,784 | 555,645 | 0.2 | 1 |
| 22 | 28May-3Jun2007 | 384,480 | 447,503 | 0.9 | 4 | 110,592 | 468,053 | 0.2 | 1 | 89,856 | 555,645 | 0.2 | 1 |

## Table A-35 Field Application Ratio on Week in PPP (Wet Season)

| week | Date | Canal 1L | | | | Canal 1L (Km.8) | | | | Canal 1L - 1L | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Vol. of Water supplied ($m^3$) | Vol. of Water demand ($m^3$) | Vs/Vd | score | Vol. of Water supplied ($m^3$) | Vol. of Water demand ($m^3$) | Vs/Vd | score | Vol. of Water supplied ($m^3$) | Vol. of Water demand ($m^3$) | Vs/Vd | score |
| 10 | 3-9 Aug. 2006 | 1,080,000 | 539,444 | 2.0 | 5 | 846,720 | 1,262,917 | 0.67 | 2 | 1,751,328 | 1,136,740 | 1.54 | 5 |
| 11 | 10-16 Aug. 2006 | 1,146,528 | 539,444 | 2.1 | 5 | 905,472 | 1,262,917 | 0.72 | 3 | 1,113,696 | 1,136,740 | 0.98 | 5 |
| 12 | 17-23 Aug. 2006 | 1,165,536 | 539,444 | 2.2 | 5 | 927,936 | 1,262,917 | 0.73 | 3 | 1,568,160 | 1,136,740 | 1.38 | 5 |
| 13 | 24-30 Aug. 2006 | 1,139,616 | 539,444 | 2.1 | 5 | 891,648 | 1,262,917 | 0.71 | 3 | 1,105,056 | 1,136,740 | 0.97 | 5 |
| 14 | 31 Aug.-6 Sep. 2006 | 1,241,568 | 539,444 | 2.3 | 5 | 986,688 | 1,262,917 | 0.78 | 3 | 1,040,256 | 1,136,740 | 0.92 | 5 |
| 15 | 7-13 Sep. 2006 | 1,216,512 | 619,058 | 2.0 | 5 | 969,408 | 1,450,605 | 0.67 | 2 | 624,672 | 1,307,306 | 0.48 | 1 |
| 16 | 14-20 Sep.2006 | 1,175,904 | 619,058 | 1.9 | 5 | 929,664 | 1,450,605 | 0.64 | 2 | 374,112 | 1,307,306 | 0.29 | 1 |
| 17 | 21-27 Sep. 2006 | 4,260,384 | 619,058 | 6.9 | 5 | 3,985,632 | 1,450,605 | 2.75 | 5 | 489,024 | 1,307,306 | 0.37 | 1 |
| 18 | 28 Sep.- 4 Oct. 2006 | 9,065,952 | 619,058 | 14.6 | 5 | 8,795,520 | 1,450,605 | 6.06 | 5 | 596,160 | 1,307,306 | 0.46 | 1 |
| 19 | 5-11 Oct. 2006 | 10,540,800 | 619,058 | 17.0 | 5 | 10,207,296 | 1,450,605 | 7.04 | 5 | 623,808 | 1,307,306 | 0.48 | 1 |
| 20 | 12-18 Oct. 2006 | 9,460,800 | 620,264 | 15.3 | 5 | 9,180,000 | 1,453,449 | 6.32 | 5 | 336,960 | 1,309,890 | 0.26 | 1 |
| 21 | 19-25 Oct. 2006 | 10,172,736 | 620,264 | 16.4 | 5 | 9,835,776 | 1,453,449 | 6.77 | 5 | 742,176 | 1,309,890 | 0.57 | 1 |
| 22 | 26-31 Oct. 2006 | 3,920,832 | 620,264 | 6.3 | 5 | 3,707,424 | 1,453,449 | 2.55 | 5 | 478,656 | 1,309,890 | 0.37 | 1 |

## Table A-35 (Cont.)

| week | Date | Canal 2L - 1L | | | | Canal 1R - 1L | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Vol. of Water supplied ($m^3$) | Vol. of Water demand ($m^3$) | Vs/Vd | score | Vol. of Water supplied ($m^3$) | Vol. of Water demand ($m^3$) | Vs/Vd | score |
| 10 | 3-9 Aug. 2006 | 252,288 | 197,836 | 1.28 | 5 | 233,280 | 128,385 | 1.82 | 5 |
| 11 | 10-16 Aug. 2006 | 296,352 | 197,836 | 1.50 | 5 | 241,056 | 128,385 | 1.88 | 5 |
| 12 | 17-23 Aug. 2006 | 250,560 | 197,836 | 1.27 | 5 | 237,600 | 128,385 | 1.85 | 5 |
| 13 | 24-30 Aug. 2006 | 234,144 | 197,836 | 1.18 | 5 | 247,968 | 128,385 | 1.93 | 5 |
| 14 | 31 Aug.-6 Sep. 2006 | 203,040 | 197,836 | 1.03 | 5 | 254,880 | 128,385 | 1.99 | 5 |
| 15 | 7-13 Sep. 2006 | 249,696 | 227,017 | 1.10 | 5 | 247,104 | 147,524 | 1.68 | 5 |
| 16 | 14-20 Sep.2006 | 151,200 | 227,017 | 0.67 | 2 | 246,240 | 147,524 | 1.67 | 5 |
| 17 | 21-27 Sep. 2006 | 155,520 | 227,017 | 0.69 | 2 | 274,752 | 147,524 | 1.86 | 5 |
| 18 | 28 Sep.- 4 Oct. 2006 | 151,200 | 227,017 | 0.67 | 2 | 270,432 | 147,524 | 1.83 | 5 |
| 19 | 5-11 Oct. 2006 | 204,768 | 227,017 | 0.90 | 5 | 333,504 | 147,524 | 2.26 | 5 |
| 20 | 12-18 Oct. 2006 | 151,200 | 227,459 | 0.66 | 2 | 280,800 | 147,814 | 1.90 | 5 |
| 21 | 19-25 Oct. 2006 | 325,728 | 227,459 | 1.43 | 5 | 336,960 | 147,814 | 2.28 | 5 |
| 22 | 26-31 Oct. 2006 | 50,112 | 227,459 | 0.22 | 1 | 213,408 | 147,814 | 1.44 | 5 |

## Table A-36 Field Application Ratio on Week in PPP (Dry Season)

| week | Date | Canal 1L | | | | Canal 1L (Km.8) | | | | Canal 1L - 1L | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Vol. of Water supplied ($m^3$) | Vol. of Water demand ($m^3$) | Vs/Vd | score | Vol. of Water supplied ($m^3$) | Vol. of Water demand ($m^3$) | Vs/Vd | score | Vol. of Water supplied ($m^3$) | Vol. of Water demand ($m^3$) | Vs/Vd | score |
| 10 | 30 Dec. 49-5 Jan.2007 | 2,408,832 | 693,464 | 3.5 | 5 | 2,207,520 | 2,442,646 | 0.90 | 5 | 1,693,440 | 2,064,006 | 0.82 | 5 |
| 11 | 6-12 Jan.2007 | 2,736,288 | 693,464 | 3.9 | 5 | 2,510,784 | 2,442,646 | 1.03 | 5 | 873,504 | 2,064,006 | 0.42 | 1 |
| 12 | 13-19 Jan.2007 | 1,627,776 | 693,464 | 2.3 | 5 | 1,414,368 | 2,442,646 | 0.58 | 1 | 1,640,736 | 2,064,006 | 0.79 | 4 |
| 13 | 20-26 Jan.2007 | 1,408,320 | 693,464 | 2.0 | 5 | 1,196,640 | 2,442,646 | 0.49 | 1 | 988,416 | 2,064,006 | 0.48 | 1 |
| 14 | 27 Jan.-2 Feb.2007 | 2,022,624 | 693,464 | 2.9 | 5 | 1,804,032 | 2,442,646 | 0.74 | 3 | 2,028,672 | 2,064,006 | 0.98 | 5 |
| 15 | 3-9 Feb.2007 | 1,478,304 | 818,158 | 1.8 | 5 | 1,270,944 | 2,875,341 | 0.44 | 1 | 1,165,536 | 2,432,479 | 0.48 | 1 |
| 16 | 10-16 Feb.2007 | 2,119,392 | 818,158 | 2.6 | 5 | 1,899,936 | 2,875,341 | 0.66 | 2 | 1,948,320 | 2,432,479 | 0.80 | 3 |
| 17 | 17-23 Feb.2007 | 3,399,840 | 818,158 | 4.2 | 5 | 3,163,104 | 2,875,341 | 1.10 | 5 | 1,238,976 | 2,432,479 | 0.51 | 1 |
| 18 | 24 Feb.-2 Mar. 2007 | 3,597,696 | 818,158 | 4.4 | 5 | 3,372,192 | 2,875,341 | 1.17 | 4 | 2,009,664 | 2,432,479 | 0.83 | 4 |
| 19 | 3-9 Mar. 2007 | 3,659,904 | 921,354 | 4.0 | 5 | 3,434,400 | 3,233,433 | 1.06 | 5 | 1,308,096 | 2,737,423 | 0.48 | 1 |
| 20 | 10-16 Mar. 2007 | 3,805,056 | 921,354 | 4.1 | 5 | 3,566,592 | 3,233,433 | 1.10 | 5 | 1,985,472 | 2,737,423 | 0.73 | 3 |
| 21 | 17-23 Mar. 2007 | 3,583,872 | 921,354 | 3.9 | 5 | 3,380,832 | 3,233,433 | 1.05 | 5 | 1,062,720 | 2,737,423 | 0.39 | 1 |
| 22 | 24-30 Mar.2007 | 2,282,688 | 921,354 | 2.5 | 5 | 2,122,848 | 3,233,433 | 0.66 | 2 | 1,719,360 | 2,737,423 | 0.63 | 2 |

## Table A-36 (Cont.)

| week | Date | Canal 2L - 1L | | | | Canal 1R - 1L | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Vol. of Water supplied ($m^3$) | Vol. of Water demand ($m^3$) | Vs/Vd | score | Vol. of Water supplied ($m^3$) | Vol. of Water demand ($m^3$) | Vs/Vd | score |
| 10 | 30 Dec. 49-5 Jan.2007 | 285,120 | 270,444 | 1.05 | 5 | 201,312 | 219,159 | 0.92 | 5 |
| 11 | 6-12 Jan.2007 | 222,912 | 270,444 | 0.82 | 4 | 225,504 | 219,159 | 1.03 | 5 |
| 12 | 13-19 Jan.2007 | 214,272 | 270,444 | 0.79 | 4 | 213,408 | 219,159 | 0.97 | 5 |
| 13 | 20-26 Jan.2007 | 221,184 | 270,444 | 0.82 | 4 | 211,680 | 219,159 | 0.97 | 5 |
| 14 | 27 Jan.-2 Feb.2007 | 265,248 | 270,444 | 0.98 | 5 | 218,592 | 219,159 | 1.00 | 5 |
| 15 | 3-9 Feb.2007 | 273,888 | 318,966 | 0.86 | 4 | 207,360 | 258,120 | 0.80 | 4 |
| 16 | 10-16 Feb.2007 | 279,936 | 318,966 | 0.88 | 4 | 219,456 | 258,120 | 0.85 | 4 |
| 17 | 17-23 Feb.2007 | 304,992 | 318,966 | 0.96 | 5 | 236,736 | 258,120 | 0.92 | 5 |
| 18 | 24 Feb.-2 Mar. 2007 | 245,376 | 318,966 | 0.77 | 3 | 225,504 | 258,120 | 0.87 | 4 |
| 19 | 3-9 Mar. 2007 | 248,832 | 359,121 | 0.69 | 2 | 225,504 | 290,363 | 0.78 | 3 |
| 20 | 10-16 Mar. 2007 | 286,848 | 359,121 | 0.80 | 3 | 238,464 | 290,363 | 0.82 | 4 |
| 21 | 17-23 Mar. 2007 | 125,280 | 359,121 | 0.35 | 1 | 203,040 | 290,363 | 0.70 | 2 |
| 22 | 24-30 Mar.2007 | 197,856 | 359,121 | 0.55 | 1 | 159,840 | 290,363 | 0.55 | 1 |

## Appendix B: Histograms, Graphs and Maps of Climate and Flow Data

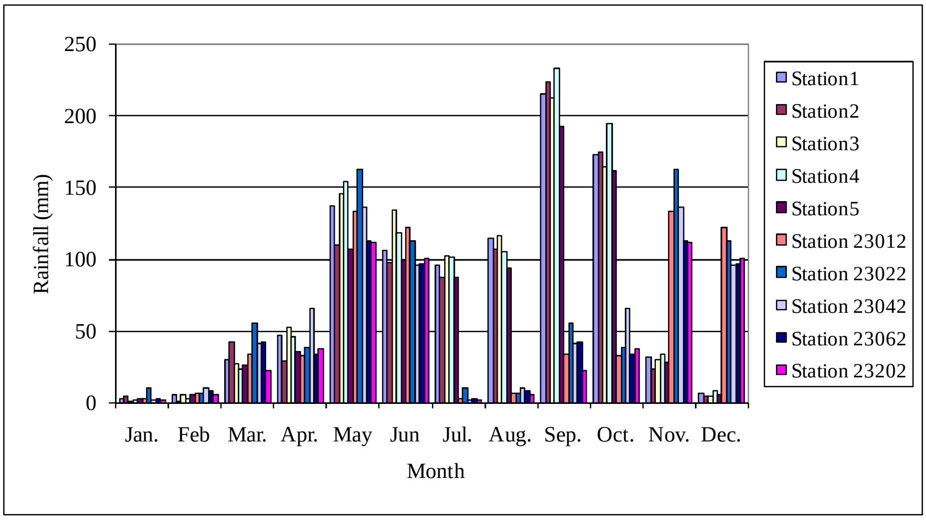



Figure B-1 Average monthly rainfall in KPP

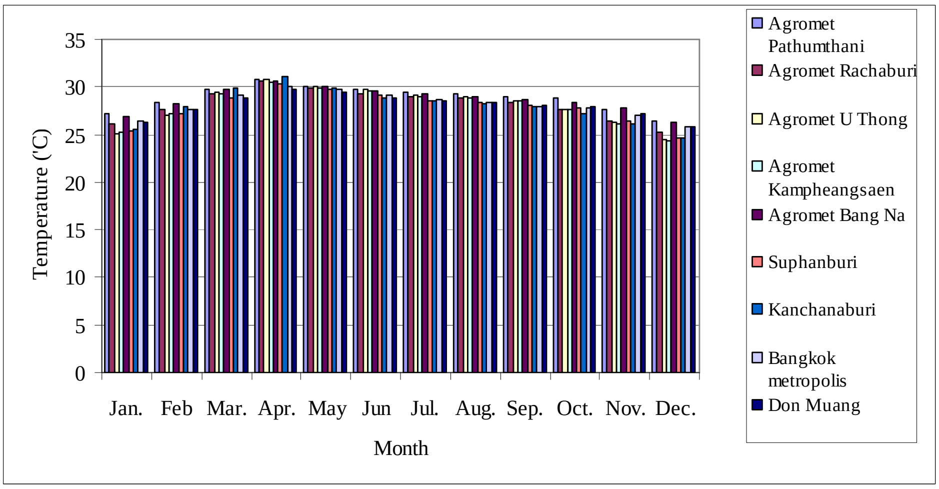



Figure B-2 Average mean temperature in KPP

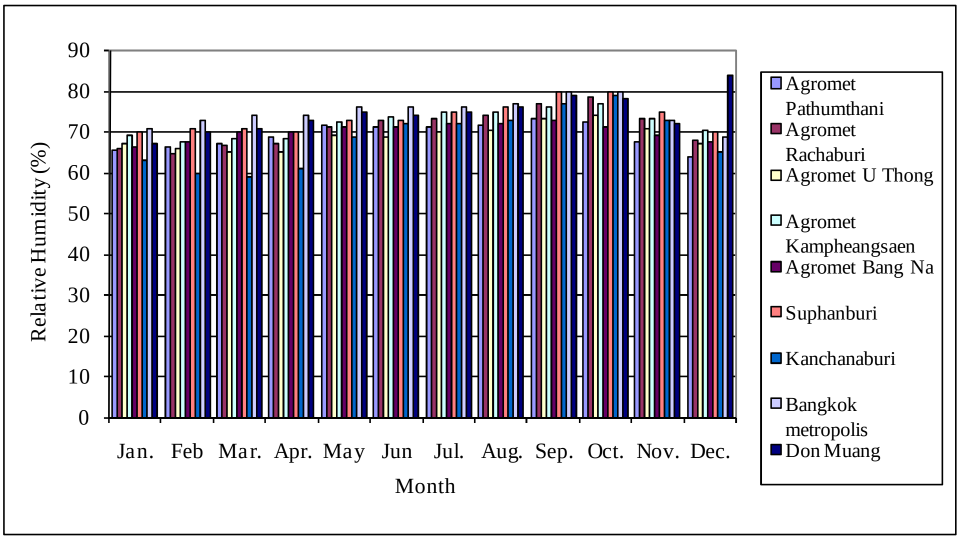



Figure B-3 Average relative humidity in KPP

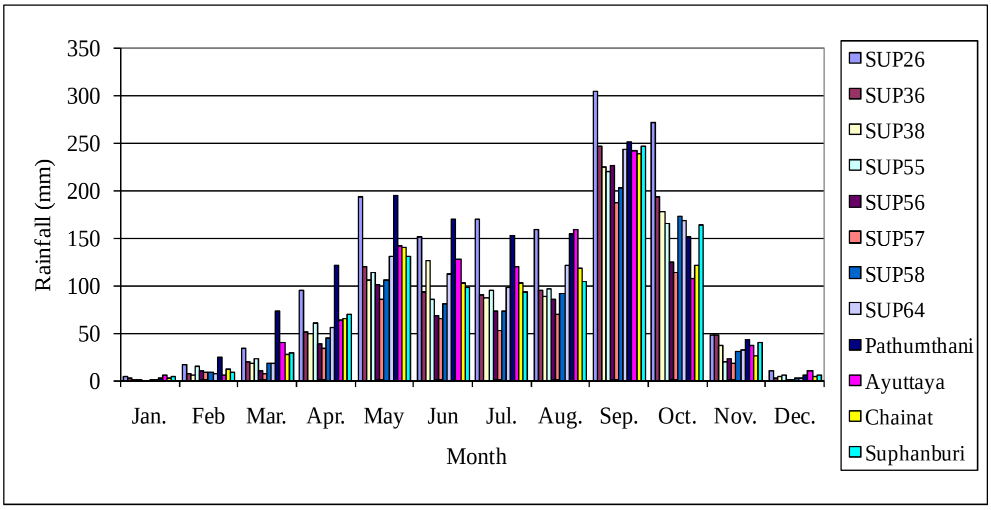



Figure B-4 Average monthly rainfall in PPP

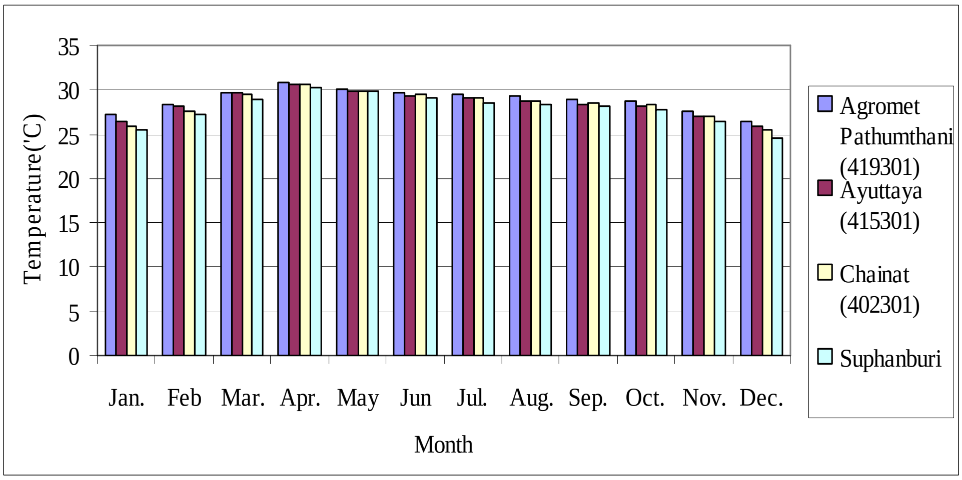



Figure B-5 Average mean temperature in PPP

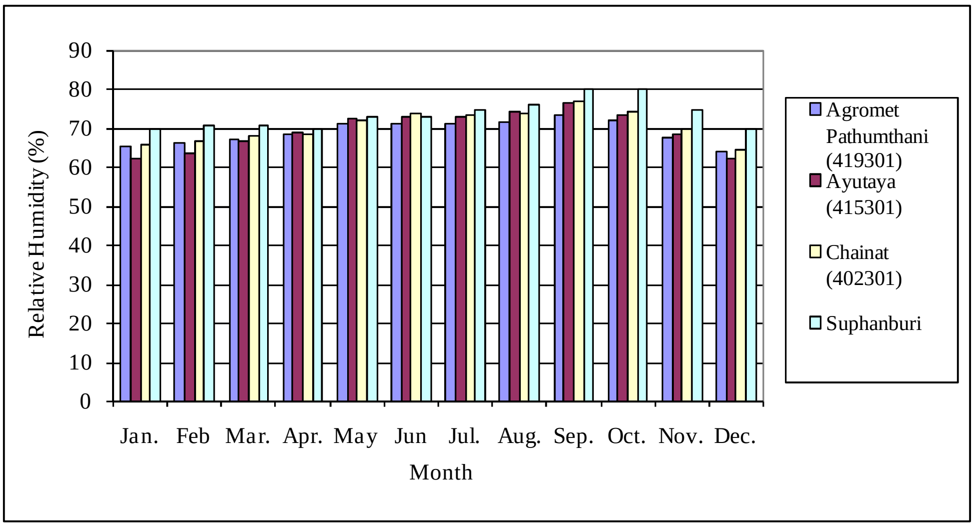



Figure B-6 Average relative humidity in PPP

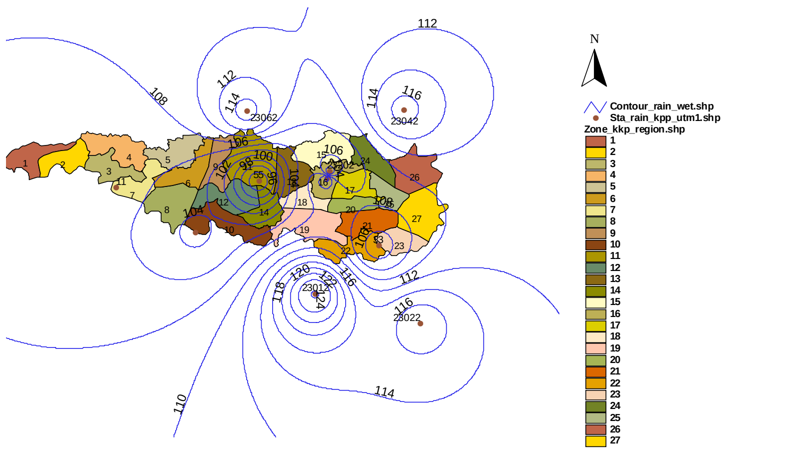


Figure B-7 Isohyets map of average monthly rainfall in KPP (wet season)

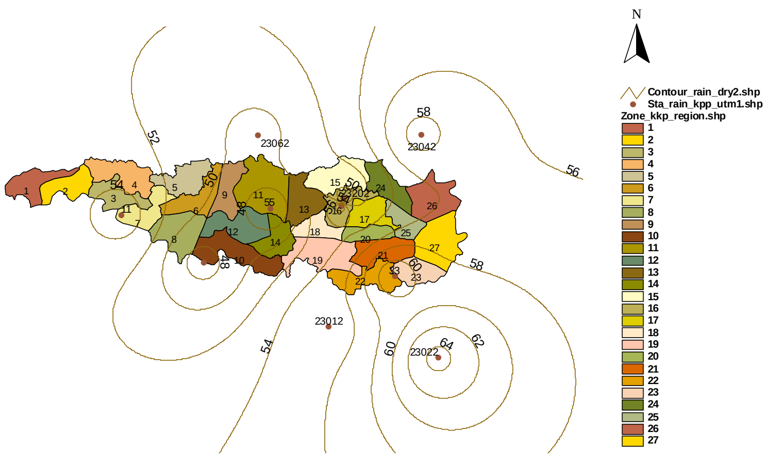


Figure B-8 Isohyets map of average monthly rainfall in KPP (dry season)

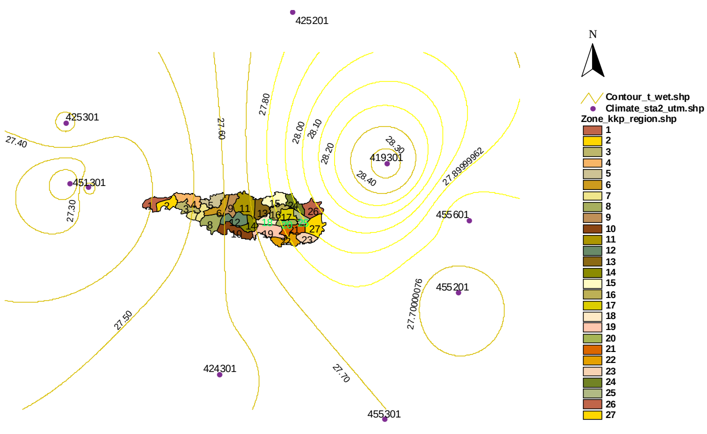


Figure B-9 Isohyets map of average mean temperature in KPP (wet season)

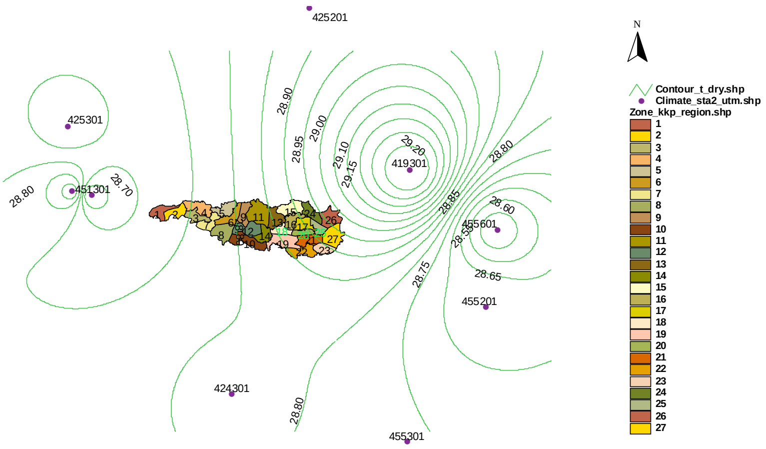



Figure B-10 Isohyets map of average mean temperature in KPP (dry season)

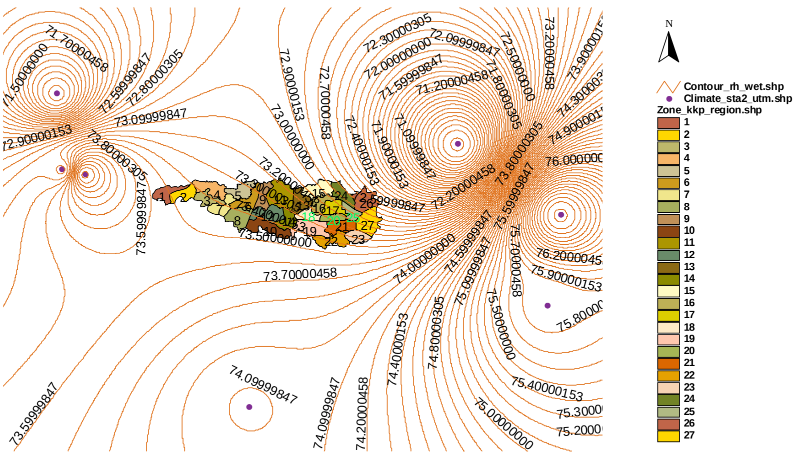



Figure B-11 Isohyets map of average relative humidity in KPP (wet season)

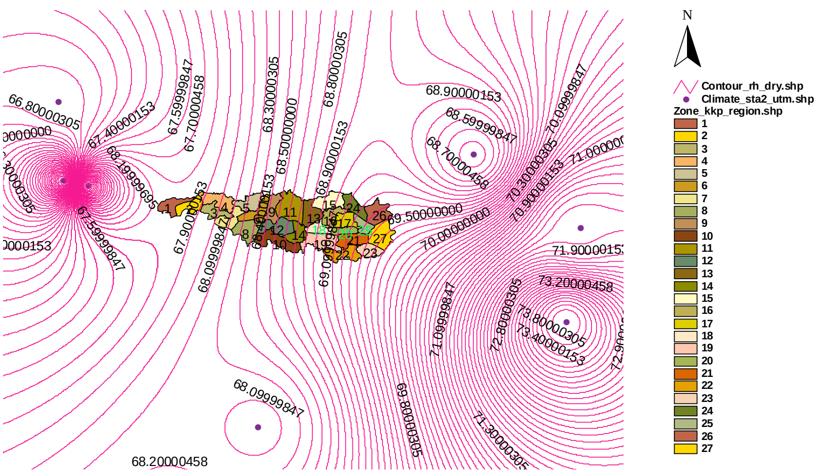



Figure B-12 Isohyets map of average relative humidity in KPP (dry season)

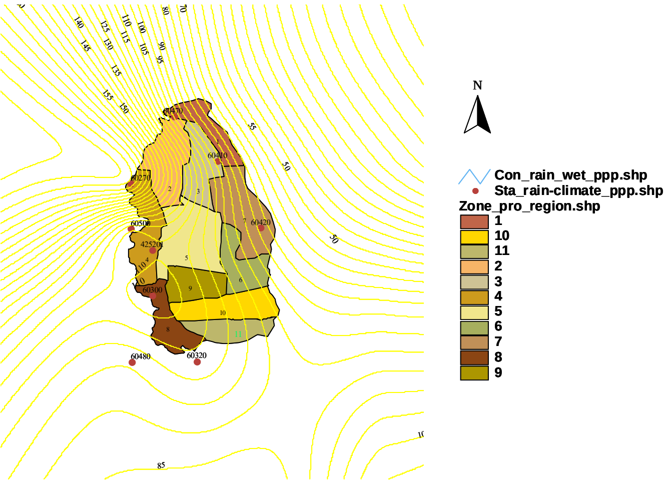



Figure B-13 Isohyets map of average monthly rainfall in PPP (wet season)

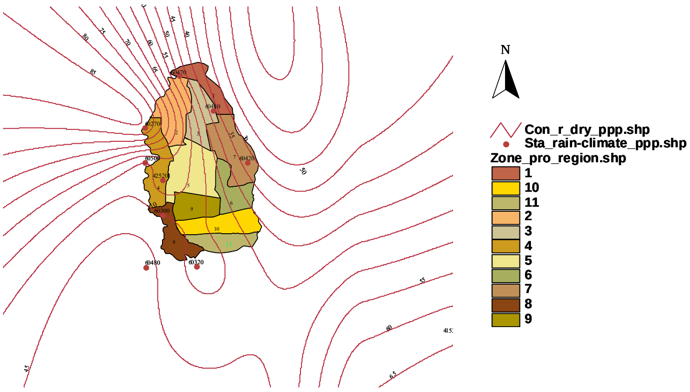



Figure B-14 Isohyets map of average monthly rainfall in PPP (dry season)

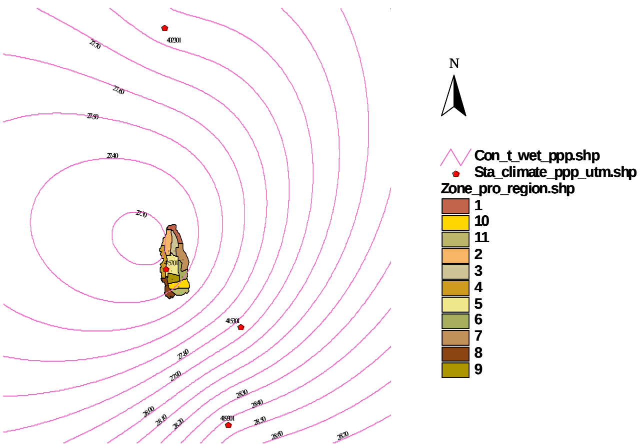



Figure B-15 Isohyets map of average mean temperature in PPP (wet season)

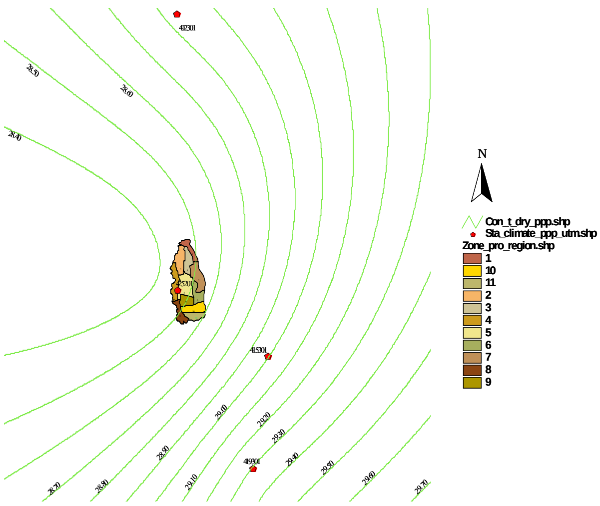



Figure B-16 Isohyets map of average mean temperature in PPP (dry season)

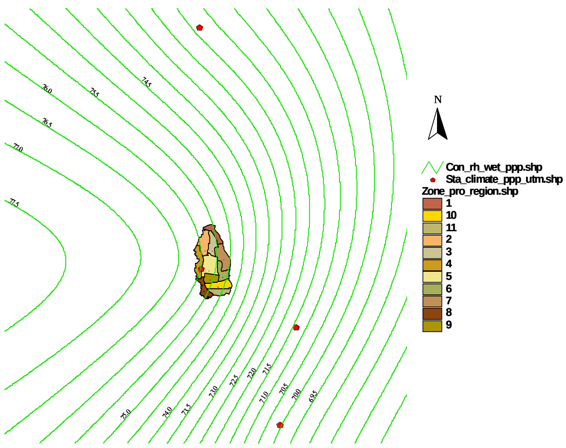



Figure B-17 Isohyets map of average relative humidity in PPP (wet season)

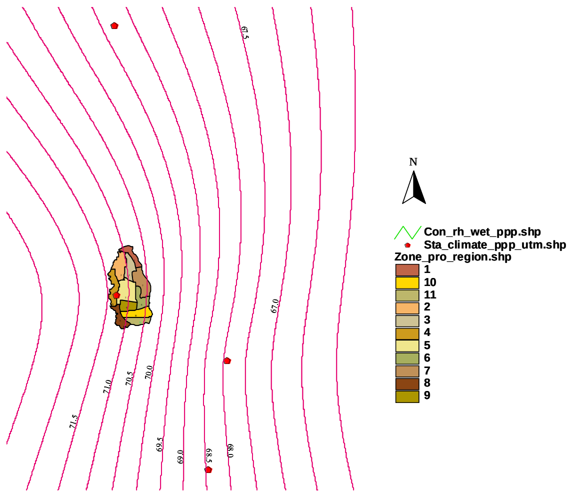
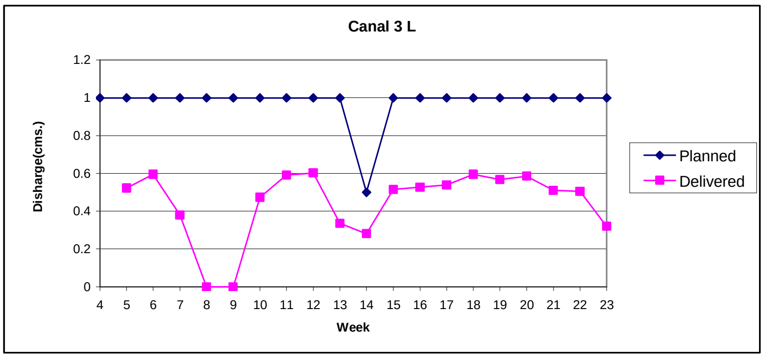
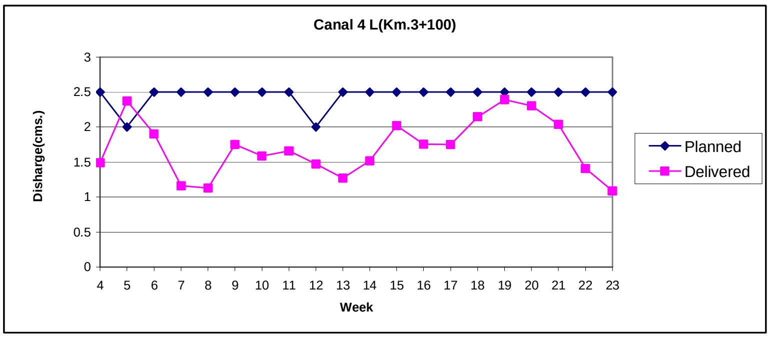
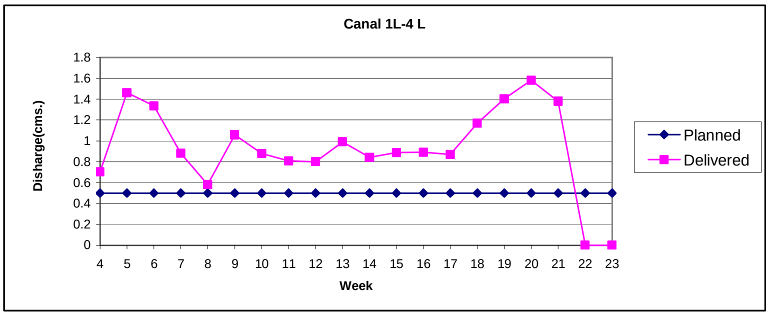
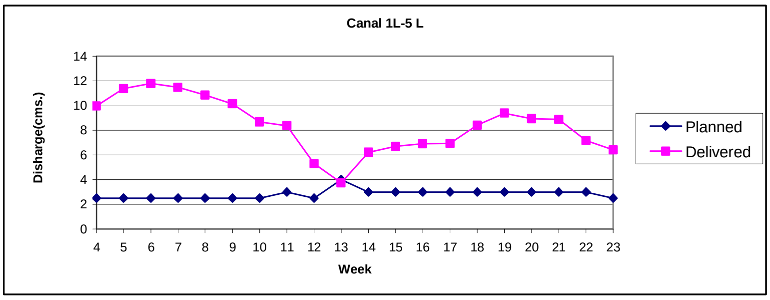



Figure B-18 Isohyets map of average relative humidity in PPP (dry season)



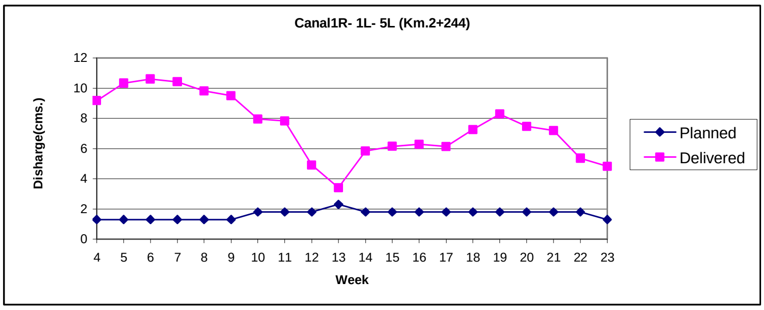
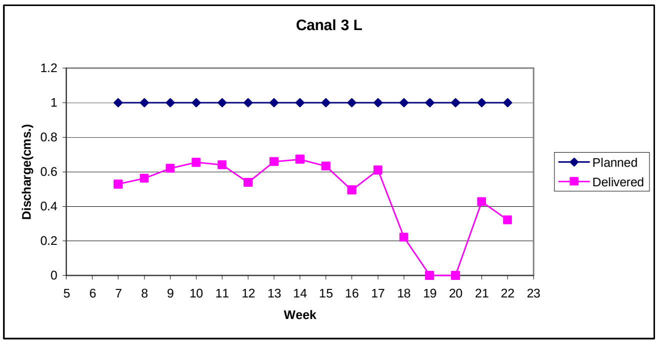
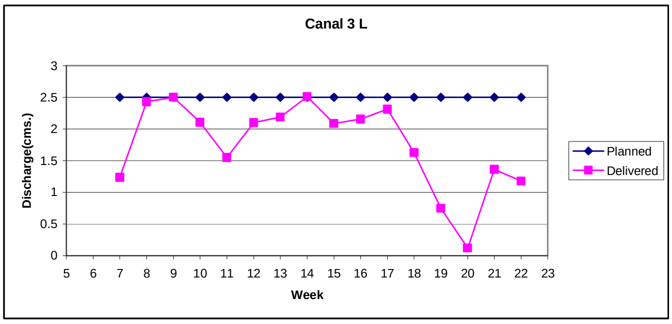
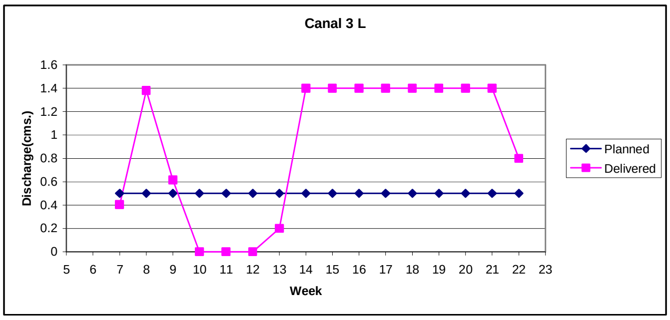
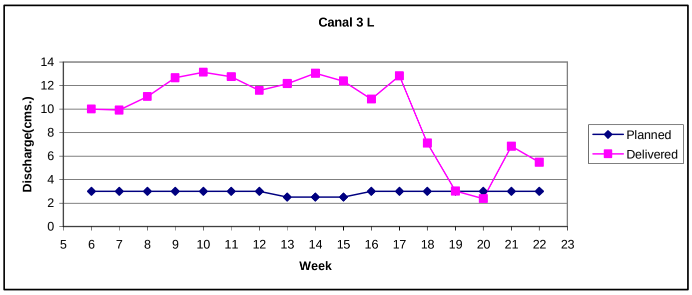




Figure B-19 Flow ratio on weekly plan in KPP (wet season)



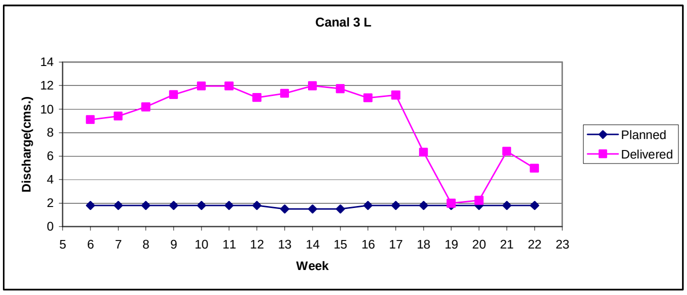
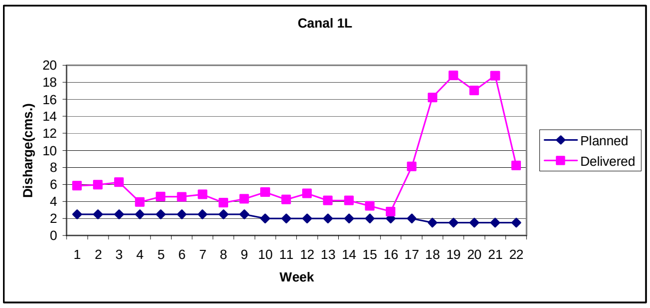
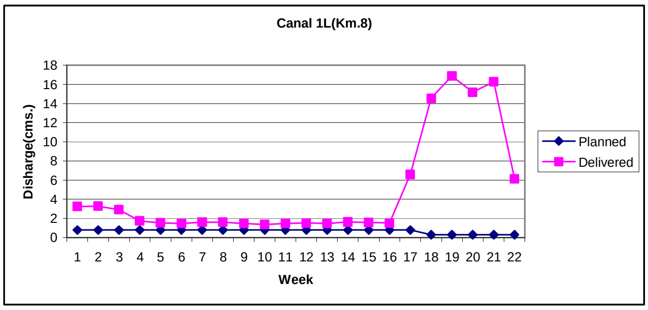
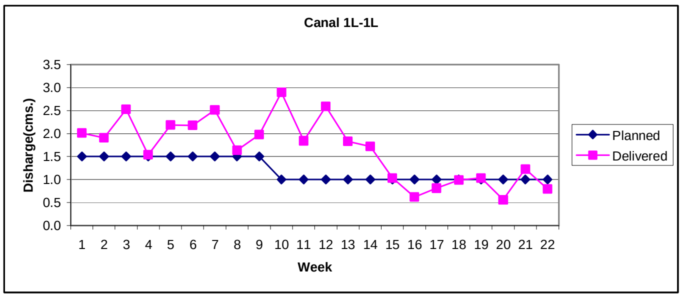
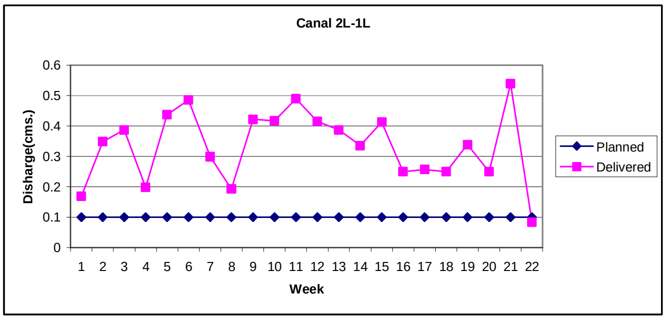




Figure B-20 Flow ratio on weekly plan in KPP (dry season)



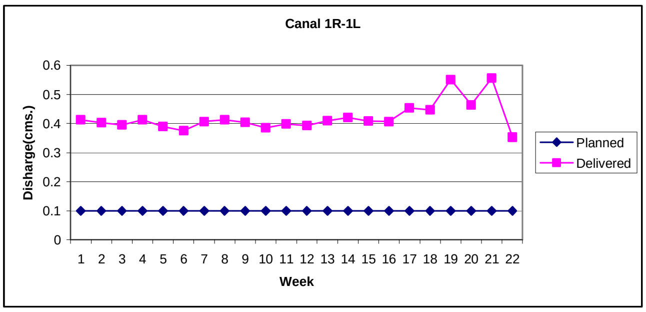
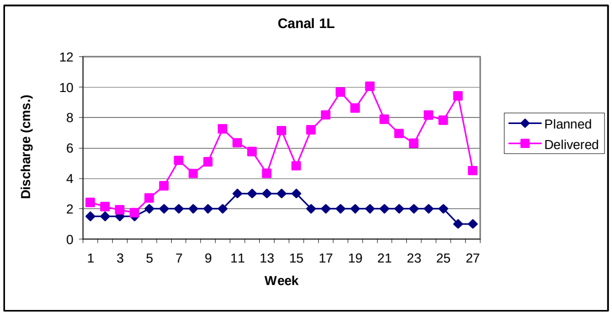
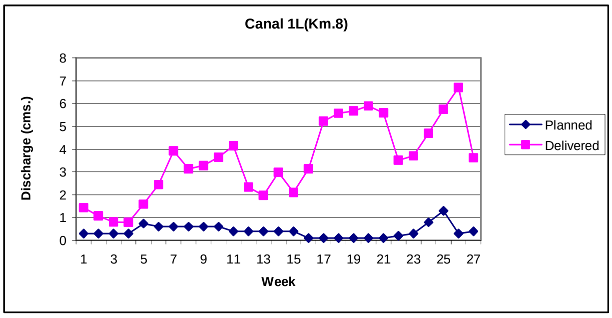
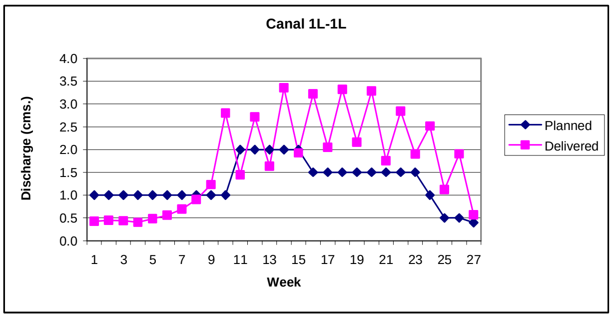
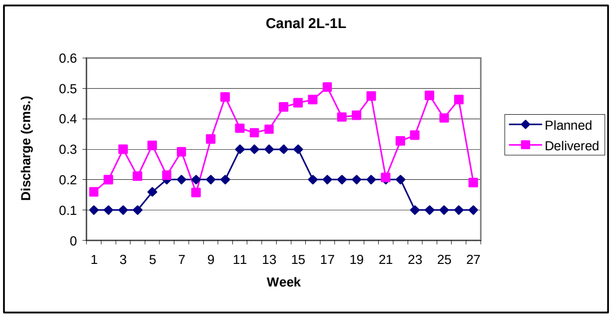




Figure B-21 Flow ratio of pre-season plan in PPP (wet season)



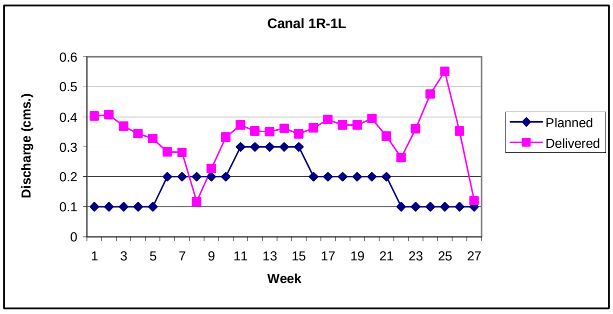




Figure B-22 Flow ratio of pre-season plan in PPP (dry season)

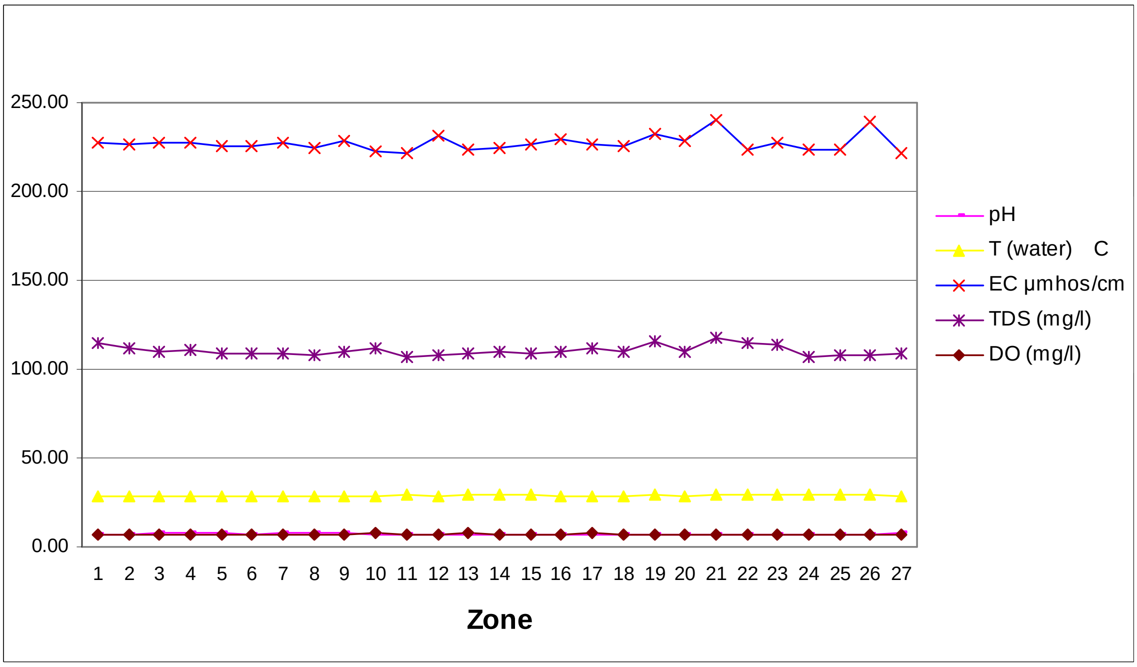



Figure B-23 Values of irrigation water quality in KPP (wet season)

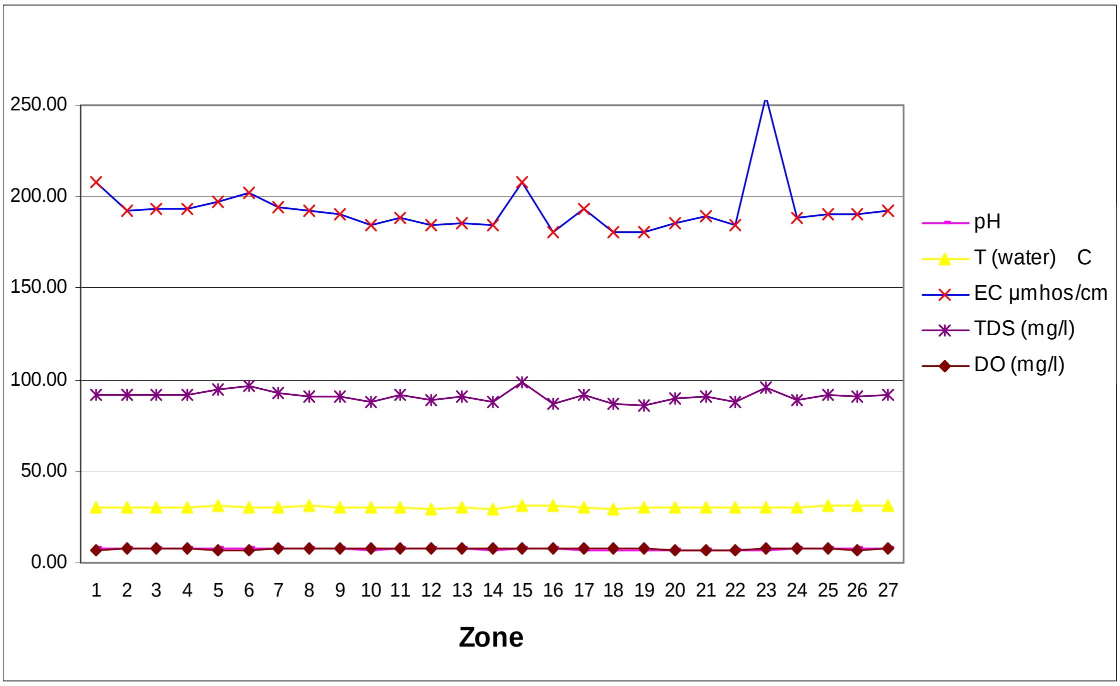



Figure B-24 Values of irrigation water quality in KPP (dry season)

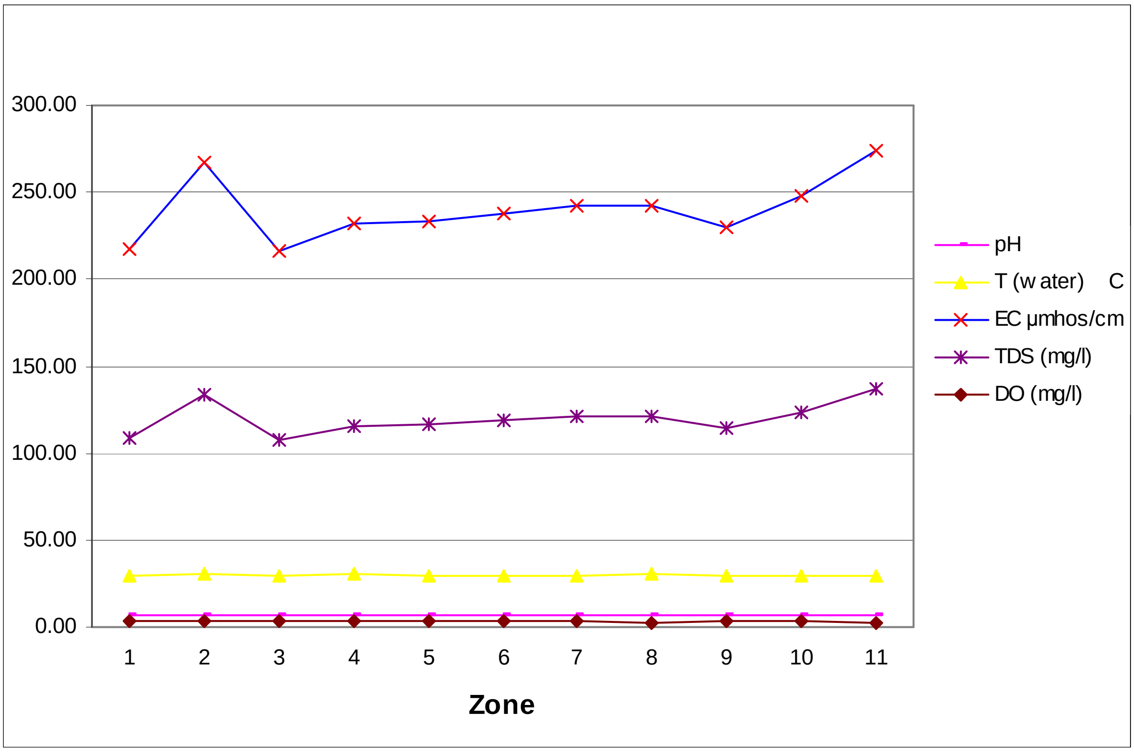



Figure B-25 Values of irrigation water quality in PPP (wet season)

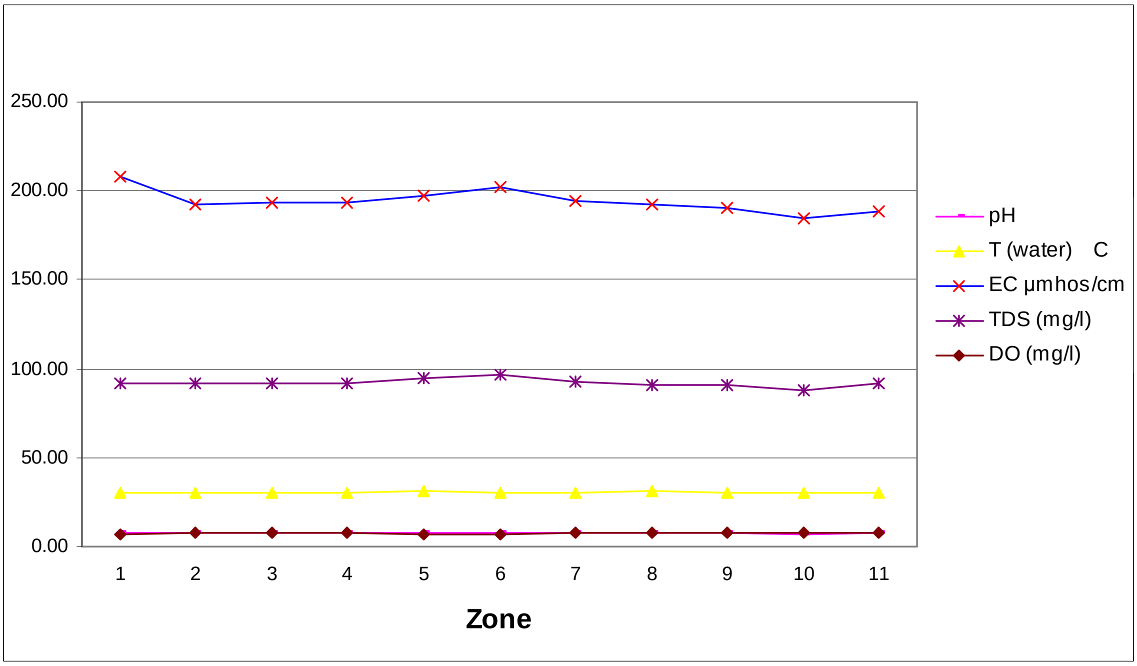



Figure B-26 Values of irrigation water quality in PPP (dry season)

**Appendix C: Field Survey Questionnaire**

**Mrs. Sanidda Tiewtoy** **Questionnaire No._____**

**An Integrated Approach to Irrigation System Assessment and Management in Selected Basins in Thailand**

# Irrigation Survey Questionnaire

## I. General Information Irrigation System

### A. General Information

1. Respondent's Name: ________________________ Telephone No.____________

2. Respondent's Address: Village _______________ Sub District _____________

District _____________________________________ Province ________________

3. Administrative Information
   - Operation and Maintenance Project Name: _________________________________
   - Water Allocation Section: ________________________________________________
   - Zone: ____________________________________
   - Name of Zone Man: ________________________

### B. Irrigation Capacity

4. Source of Water
   - [ ] Irrigation water
   - [ ] Drain water
   - [ ] Groundwater

5. Location of Sub-main Canal in the field.
   - [ ] Upstream
   - [ ] Middle
   - [ ] Downstream

6 Distribution water to Individual Field
   - [ ] By pumping
   - [ ] By gravity
   - [ ] Other (specify) ________________________________

7. Crop calendar

| Name of Crop | Dry Season | | | | | | Wet Season | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | April | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1. | | | | | | | | | | | | |
| 2. | | | | | | | | | | | | |
| 3. | | | | | | | | | | | | |

8. Water supply

| Dry Season | Dry season | | |
|---|---|---|---|
| | 1st crop | 2nd crop | 3rd crop |
| 8.1) Crop name | | | |
| 8.2) Area cultivated (Rai) | | | |
| 8.3) Irrigated area (Rai) | | | |
| 8.4) How many times do farmer get irrigation water during the crop cycle | | | |
| 8.5) How many hours irrigation water delivery to the field per one time | | | |

| Wet season | Wet season | | |
|---|---|---|---|
| | 1st crop | 2nd crop | 3rd crop |
| 8.6) Crop name | | | |
| 8.7) Area cultivated (Rai) | | | |
| 8.8) Irrigated area (Rai) | | | |
| 8.9) How many times do farmer get irrigation water during the crop cycle | | | |
| 8.10) How many hours irrigation water delivery to the field per one time | | | |

8.11 What is the characteristic of pump ?

Diameter of pipe __________inch.
Horse power ______________Hp.
Head of water m.

8.12 (In case, used sprinkler)

- Brand of nozzle ________________Colour of nozzle ____________________
- Discharge of nozzle (l/s)__________How many hours using sprinkler(hr)______

8.13. What is the water level at the field rice from ground_________________(cm.)

8.14 What is the dimension of furrow in sugar cane field_________________m.

9. Have you had groundwater pumping well?

[ ] Yes [ ] No

10 When you provide to use it?

[ ] Irrigated area higher than water source
[ ] Inadequate water in dry season
[ ] Irrigation water is not come through
[ ] Other (specify)_____________________________

11. How many times you use it during the crop cycle? ____________________
How many hours per one time? _____________
Total head of water______________________(m.) Horse power _____________Hp.

12. Who is responsible for delivering water from canal to field?

[ ] Farmer's group [ ] WUA
[ ] RID's staff [ ] Other specify)___________________________

13. What are the provisions of management if there is less irrigation water available than required?______________________________________________________________

14. Type of irrigation Practice

[ ] Surface (furrow, border, basin)
[ ] Sub surface (drip)
[ ] Over head (sprinkler irrigation)
[ ] Other (specify) _______________________________

15. Type of canal level to the field

[ ] Main [ ] Secondary
[ ] Tertiary [ ] Quaternary

16. Canal network has deposit, weed (wet season)

[ ] High [ ] Moderate
[ ] Low [ ] Never

17. Canal network has deposit, weed (dry season)

[ ] High [ ] Moderate
[ ] Low [ ] Never

18. Frequency of canal maintenance such as weed control (wet season)

[ ] Frequently (more than 4 times) [ ] Occasionally (3 times)
[ ] Rarely (1-2 times) [ ] Never

19. Frequency of canal maintenance such as weed control (dry season)

[ ] Frequently (more than 4 times) [ ] Occasionally (3 times)
[ ] Rarely (1-2 times) [ ] Never

20. Relative position of irrigated area to water source

[ ] Above [ ] Same level
[ ] Below

21. Drainage system at the field

[ ] Yes [ ] No

22. Condition of drainage

[ ] Good drain [ ] Medium drain
[ ] Poor drain

23. Type of drainage system

[ ] Surface [ ] Sub surface
[ ] Other (specify) _______________________________

**C. Household Characteristics**

24. Farmer's information

| Name | Year of agricultural practice | Status | Sex | Age | Education | Main occupation | Household member |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |

25. Land area (Rai)____________________

26.1) Land tenure size (Rai)________26.2) Price for rent land________(Baht/Rai/Year)

**D. Crop**

27. The crop same last year?

[ ] Yes [ ] No

[ ] Other (specify) _________________________________

28. Reason for change crop

[ ] Market price [ ] Tradition

[ ] RID's policy

[ ] Other (specify) _________________________________

**E. Financial**

a. Farm Input Cost

| Description | Dry season | | | Wet season | | |
|---|---|---|---|---|---|---|
| | 1st crop | 2nd crop | 3rd crop | 1st crop | 2nd crop | 3rd crop |
| 29) Seed | | | | | | |
| a) | | | | | | |
| - quantity/unit | | | | | | |
| - price (price/unit) | | | | | | |
| - total cost | | | | | | |
| b) | | | | | | |
| - quantity/unit | | | | | | |
| - price (price/unit) | | | | | | |
| - total cost | | | | | | |
| c) | | | | | | |
| - quantity/unit | | | | | | |
| - price (price/unit) | | | | | | |
| - total cost | | | | | | |
| 30) Fertilizer | | | | | | |
| a) | | | | | | |
| - quantity/unit | | | | | | |
| - price (price/unit) | | | | | | |
| - total cost | | | | | | |
| b) | | | | | | |
| - quantity/unit | | | | | | |
| - price (price/unit) | | | | | | |
| - total cost | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| c) | | | | | | |
| - quantity/unit | | | | | | |
| - price (price/unit) | | | | | | |
| - total cost | | | | | | |
| 31.) Pesticide and Herbicide | | | | | | |
| a) | | | | | | |
| - quantity/unit | | | | | | |
| - price (price/unit) | | | | | | |
| - total cost | | | | | | |
| b) | | | | | | |
| - quantity/unit | | | | | | |
| - price (price/unit) | | | | | | |
| - total cost | | | | | | |
| c) | | | | | | |
| - quantity/unit | | | | | | |
| - price (price/unit) | | | | | | |
| - total cost | | | | | | |

E. Cond't

| Description | Dry season | | | Wet season | | |
|---|---|---|---|---|---|---|
| | 1st crop | 2nd crop | 3rd crop | 1st crop | 2nd crop | 3rd crop |
| 32) Other Materials | | | | | | |
| - quantity/unit | | | | | | |
| - price (price/unit) | | | | | | |
| - total cost | | | | | | |
| 33) Pumping | | | | | | |
| - energy (price/hr.) | | | | | | |
| - time (hr.) | | | | | | |
| - maintenance | | | | | | |
| - total cost | | | | | | |
| 34)Other | | | | | | |
| - farm machine | | | | | | |
| - travel(gasoline) | | | | | | |
| | | | | | | |

b. Labor Cost

| Description | Dry season | | | Wet season | | |
|---|---|---|---|---|---|---|
| | 1st crop | 2nd crop | 3rd crop | 1st crop | 2nd crop | 3rd crop |
| 35) Land Preparation | | | | | | |
| a) man/day | | | | | | |
| b) hours/day | | | | | | |
| c) wage/day | | | | | | |
| d) total wage | | | | | | |
| 36) Seeding and Planting | | | | | | |
| a) man/day | | | | | | |
| b) hours/day | | | | | | |
| c) wage/day | | | | | | |
| d) total wage | | | | | | |

| 37) Harvesting Cost | | | | | | |
|---|---|---|---|---|---|---|
| a) man/day | | | | | | |
| b) hours/day | | | | | | |
| c) wage/day | | | | | | |
| d) total wage | | | | | | |

c. Other Cost

38. Fee (sugar cane, operation and maintenance cost)____________________Baht/Year

**F. Income**

a. Production cost

| Description | Dry season | | | Wet season | | |
|---|---|---|---|---|---|---|
| | 1st crop | 2nd crop | 3rd crop | 1st crop | 2nd crop | 3rd crop |
| 39. Area cultivated (Rai) | | | | | | |
| 40. Area harvested (Rai) | | | | | | |
| 41. Crop production (Kg./Rai) | | | | | | |
| 42. Self consumption (kg) | | | | | | |

b. Selling and Farm Revenue

| Description | Dry season | | | Wet season | | |
|---|---|---|---|---|---|---|
| | 1st crop | 2nd crop | 3rd crop | 1st crop | 2nd crop | 3rd crop |
| 43. Price of crop at farm (Baht) | | | | | | |
| 44. Market price (Baht) | | | | | | |

**G. Total Cost**

| Description | Dry season | | | Wet season | | |
|---|---|---|---|---|---|---|
| | 1st crop | 2nd crop | 3rd crop | 1st crop | 2nd crop | 3rd crop |
| Total Production (price/ha) | | | | | | |
| Total Income (price/ha) | | | | | | |

**H. Management**

**a) Water Distribution**

| 45. What is your satisfaction degree on : | Degree of Satisfaction | | | | |
|---|---|---|---|---|---|
| | Strongly dissatisfied | Dissatisfied | Neutral | Satisfied | Strongly satisfied |
| Cultivated areas survey by WUG before irrigation season | | | | | |
| Planning of water delivery schedule by RID staffs and WUG | | | | | |
| Meeting between Chief of WUG and WUG for | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| schedule planning agreement | | | | | |
| Listen to the opinion of WUG listening by RID staffs | | | | | |
| Announcement of the irrigation schedule to all WUG | | | | | |
| Adequacy of water distribution | | | | | |
| Matching of farm operations with RID water delivery | | | | | |
| Reliability of continuous flow | | | | | |
| Canal/ditch condition (clean/smooth) | | | | | |
| Canal/ditch drainage condition (clean/smooth) | | | | | |
| Accountability of timeliness and fairness of water distribution | | | | | |

**b) Conflict**

46. Have you had an experience with water conflict?

[ ] Frequently (more than 5 times) [ ] Occasionally (4 times)
[ ] Rarely (2-3 times) [ ] Never

47. Source of conflict

[ ] Inadequacy of water
[ ] Unsatisfactorily timeliness and duration of water distribution
[ ] No priority concern on fairness of water flow
[ ] Disregard the reliability on water distribution
[ ] Other (specify) ________________________________

48. Who is solving about this confliction?

[ ] Farmer's group [ ] WUA
[ ] RID's staff
[ ] Other such as_____________________________

49. What is your satisfaction degree on conflict solving?

[ ] Strongly satisfied [ ] Satisfied
[ ] Neutral [ ] Dissatisfied
[ ] Strongly dissatisfied

50. Which is the regulation used in this area?

[ ] No. regulation [ ] Fine
[ ] Disqualify from water use
[ ] Other (specify)_____________________________

51. What is the sanction/punishment used?

[ ] No [ ] Fine
[ ] Disqualify from membership of water use [ ] Boycott
[ ] Disqualify from water use
[ ] Other (specify)______________________

52. There is punishment water user who is denies the regulation.

[ ] Yes, because___________________________
[ ] No, because____________________________

53. How can this problem be prevented in the future?____________________________
______________________________________________________________________

**I. Institutional**

54. Obstacle in administration of water user group

[ ] Lack of cooperative with membership [ ] Lack of support from RID
[ ] Lack of financial support [ ] Poor administrative capability
[ ] Poor structure of water user group

55. Awareness on irrigation water use.

[ ] Very good [ ] Good
[ ] Undecided [ ] Bad
[ ] Worst

56. Perception on soil erosion.

[ ] Very good [ ] Good
[ ] Undecided [ ] Bad
[ ] Worst

57. Awareness on drained water quality.

[ ] Very good [ ] Good
[ ] Undecided [ ] Bad
[ ] Worst

58. Awareness on soil quality.

[ ] Very good [ ] Good
[ ] Undecided [ ] Bad
[ ] Worst

59. How are farmers communicate with RID's staff?

[ ] Telephone [ ] Letter
[ ] WUA [ ] Personal
[ ] Other (specify) _________________________________

60. Satisfaction degree on promotion of RID staff

[ ] Strongly satisfied [ ] Satisfied
[ ] Neutral [ ] Dissatisfied
[ ] Strongly dissatisfied

61. The information has benefit to water user group.

[ ] Strongly satisfied [ ] Satisfied
[ ] Neutral [ ] Dissatisfied
[ ] Strongly dissatisfied

62. What type of information will help to better manage irrigated land?

[ ] Irrigation equipment innovations
[ ] Crop water requirement & irrigation scheduling guidelines
[ ] Soil management guidelines
[ ] Other (specify) ___________________________________

63. Type of training generally used for irrigation management?

[ ] PIM [ ] Water saving
[ ] Water harvesting
[ ] Other (specify) ___________________________________

64. Farmer (or your household members) received technical training in agriculture or on farm water management in the last 2 years.

[ ] Frequently (more than 5 times) [ ] Occasionally (4 times)
[ ] Rarely (2-3 times) [ ] Never

65. How often have you attended meeting?

[ ] Frequently (more than 5 times) [ ] Occasionally (4 times)
[ ] Rarely (2-3 times) [ ] Never

66. Who is responsible for this training?

[ ] RID staff [ ] WUA
[ ] Extension club
[ ] Other (specify) __________________________________

67. Do you pay any fees for water?

[ ] Yes, How much per volume are collected________(Baht/ $m^3$)
[ ] No

68. Use of collected water fee?

[ ] Maintenance and repair
[ ] Upgrading and new construction
[ ] Remuneration for management
[ ] Operational cost
[ ] Other (specify) __________________________________

69. Who is responsible organization for collecting fee?

[ ] WUA [ ] Farmer Group
[ ] RID Staff
[ ] Other (specify) ________________________________

70. Willingness to pay.

[ ] Very high [ ] High
[ ] Undecided [ ] Low
[ ] Very Low

71. Price of water which you can pay (Baht/$m^3$)___________or __________(Baht/Rai)

72. Source of financial support

[ ] No [ ] User's irrigation service fee
[ ] Water contribution fee [ ] Government (RID)
[ ] External support________________________________
[ ] Other (specify) ________________________________

73. Who is responsible for maintenance and operation at the field?

[ ] WUA [ ] Farmer Group
[ ] RID Staff
[ ] Other (specify) ________________________________

**J. Environment**

74. Satisfaction degree on quality of irrigation water?

[ ] Strongly satisfied
[ ] Satisfied
[ ] Neutral
[ ] Dissatisfied
[ ] Strongly satisfied

75. Satisfaction degree on soil fertility of irrigable area?

[ ] Strongly satisfied
[ ] Satisfied
[ ] Neutral
[ ] Dissatisfied
[ ] Strongly satisfied

76. Do you have a problem with alkaline soil?

[ ] High
[ ] Medium
[ ] Low
[ ] Other (specify) ___________________________________

77. Type of soil erosion conservation practice?

[ ] No
[ ] Mulching
[ ] Crop rotation
[ ] Tillage
[ ] Strip cropping
[ ] Grass/bamboo barrier
[ ] Stone bund
[ ] Other (specify) ___________________________________

78. Have you ever experience flood in this field?

[ ] No
[ ] Every year
[ ] Twice a year
[ ] Depend on depression
[ ] Occasion

79. How to manage flood protection?_______________________________________

80. Type of crop residue treatment?

[ ] Mainly burning
[ ] Mainly return to the soil
[ ] Mainly for forage
[ ] Other (specify) ___________________________________

Additional comments: Please provide any additional information, comments, or suggestions, which may be useful for improving of irrigation management in this area.

___________________________________________________________________________

Name_____________________________________

Data Entry_________________________________

**Appendix D: Summary of Data from Questionnaires**

Table D-1 Physical Variables of Each Zone in KPP

| Zone | V1= Location of Sub-Main Canal in the Field | V2= Relative Position of Irrigated Area to Water Resource | V3= Ditch condition (clean/smooth) | V4= Drainage ditch condition (clean/smooth) | V5= Flooding frequency |
|---|---|---|---|---|---|
| 1 | 2 | 1 | 3.0 | 3.0 | 1 |
| 2 | 2 | 2 | 3.0 | 3.0 | 4 |
| 3 | 2 | 3 | 2.6 | 2.6 | 2 |
| 4 | 2 | 2 | 2.8 | 2.5 | 1 |
| 5 | 2 | 2 | 2.8 | 2.5 | 1 |
| 6 | 2 | 3 | 2.6 | 2.5 | 2 |
| 7 | 2 | 2 | 2.8 | 3.0 | 1 |
| 8 | 2 | 2 | 2.4 | 2.5 | 2 |
| 9 | 2 | 2 | 3.5 | 3.1 | 3 |
| 10 | 2 | 2 | 3.2 | 3.1 | 2 |
| 11 | 2 | 1 | 3.8 | 3.7 | 4 |
| 12 | 2 | 2 | 2.9 | 2.7 | 3 |
| 13 | 2 | 2 | 3.5 | 3.1 | 3 |
| 14 | 3 | 2 | 2.9 | 2.8 | 2 |
| 15 | 2 | 3 | 3.3 | 3.3 | 1 |
| 16 | 2 | 2 | 3.1 | 3.0 | 3 |
| 17 | 2 | 3 | 3.1 | 3.2 | 4 |
| 18 | 2 | 3 | 3.3 | 3.1 | 3 |
| 19 | 2 | 3 | 2.9 | 2.9 | 2 |
| 20 | 2 | 3 | 3.0 | 3.0 | 3 |
| 21 | 2 | 2 | 3.3 | 3.1 | 3 |
| 22 | 2 | 2 | 2.9 | 2.7 | 2 |
| 23 | 2 | 3 | 3.4 | 3.2 | 3 |
| 24 | 2 | 3 | 3.2 | 2.9 | 2 |
| 25 | 2 | 3 | 3.3 | 3.3 | 3 |
| 26 | 2 | 3 | 2.3 | 2.1 | 3 |
| 27 | 2 | 3 | 3.3 | 3.3 | 1 |

The meaning of variable (V)

**V1;** 1= Upstream, 2=Middle, 3= Downstream
**V2;** 1=Higher slope, 2=Average the same level, 3=Lower slope
**V3;** 1=Strongly dissatisfied, 2= Dissatisfied, 3= Neutral, 4= Satisfied, 5= Strongly satisfied
**V4;** 1=Strongly dissatisfied, 2= Dissatisfied, 3= Neutral, 4= Satisfied, 5= Strongly satisfied
**V5;** 1=no flood within 2-3 recent years, 2=every year, 3=twice a year, 4=dependent on depression, 5=occasionally

Table D-2 Socio-Economic Variables of Each Zone in KPP

| Zone | V6= Sex | V7= Age structure | V8= Education | V9= Experience of farmer | V10= House hold size | V11= Land tenure | V12= Awareness on irrigation water use | V13= Water user conflict occurrence |
|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 2.85 | 2.30 | 1.54 | 2.32 | 2.74 | 2.18 | 1.35 |
| 2 | 1 | 2.92 | 2.28 | 2.79 | 2.54 | 3.87 | 3.28 | 1.05 |
| 3 | 1 | 3.22 | 2.13 | 3.20 | 2.36 | 5.00 | 3.00 | 1.03 |
| 4 | 1 | 3.00 | 2.28 | 2.73 | 2.48 | 4.60 | 4.24 | 1.92 |
| 5 | 1 | 3.00 | 2.28 | 2.73 | 2.48 | 4.60 | 4.24 | 1.06 |
| 6 | 1 | 2.95 | 2.57 | 2.00 | 2.54 | 3.86 | 4.53 | 1.86 |
| 7 | 1 | 2.86 | 2.44 | 1.00 | 2.44 | 5.00 | 3.44 | 1.58 |
| 8 | 1 | 2.83 | 2.33 | 1.61 | 2.53 | 4.75 | 4.03 | 1.58 |
| 9 | 1 | 2.63 | 2.26 | 2.23 | 2.49 | 3.88 | 4.15 | 1.84 |
| 10 | 1 | 3.07 | 2.29 | 2.85 | 2.75 | 1.83 | 4.62 | 2.00 |
| 11 | 1 | 3.22 | 2.12 | 2.98 | 2.75 | 4.68 | 3.73 | 1.52 |
| 12 | 1 | 2.87 | 2.13 | 2.78 | 2.50 | 4.75 | 4.50 | 1.71 |
| 13 | 1 | 2.63 | 2.26 | 2.23 | 2.49 | 3.88 | 4.15 | 1.93 |
| 14 | 1 | 3.05 | 2.30 | 2.35 | 2.45 | 2.42 | 4.39 | 2.06 |
| 15 | 1 | 2.55 | 1.93 | 2.07 | 3.14 | 4.33 | 5.00 | 1.00 |
| 16 | 1 | 3.00 | 2.27 | 2.38 | 2.57 | 3.03 | 3.87 | 1.39 |
| 17 | 1 | 2.62 | 2.20 | 2.13 | 2.55 | 1.90 | 4.36 | 1.73 |
| 18 | 1 | 2.73 | 2.31 | 2.21 | 2.66 | 4.23 | 3.96 | 1.80 |
| 19 | 1 | 3.07 | 2.27 | 2.21 | 2.95 | 3.05 | 4.42 | 1.10 |
| 20 | 1 | 3.15 | 2.26 | 2.03 | 3.01 | 3.67 | 3.97 | 1.82 |
| 21 | 1 | 3.13 | 2.18 | 2.21 | 2.51 | 3.81 | 4.49 | 1.45 |
| 22 | 1 | 2.83 | 2.29 | 1.87 | 2.80 | 3.00 | 4.22 | 1.69 |
| 23 | 1 | 3.23 | 2.38 | 3.21 | 2.68 | 2.75 | 4.10 | 1.81 |
| 24 | 1 | 2.86 | 2.00 | 2.24 | 2.30 | 4.92 | 4.67 | 1.98 |
| 25 | 1 | 3.14 | 2.02 | 2.45 | 3.17 | 5.00 | 4.21 | 1.51 |
| 26 | 1 | 3.19 | 2.14 | 2.81 | 2.67 | 4.60 | 4.40 | 1.81 |
| 27 | 1 | 3.16 | 2.03 | 2.61 | 2.47 | 5.00 | 4.57 | 1.99 |

The meaning of variable (V)

**V6;** 1=Male, 2=Female

**V7;** 1=less than 35 years, 2=35-45 years, 3=46-55 years, 4=56-65 years, 5= more than 65 years

**V8;** 1=no education, 2=elementary, 3=secondary, 4=high school, 5=college/university, 6 more than university

**V9;** 1=less than 15 years, 2=15-26 years, 3=26-35 years, 4=36-45 years, 5= more than 45 years

**V10;** 1=less than 2 persons, 2=3-4 persons, 3=5-6 persons, 4=7-8 persons, 5= more than 9 persons

**V11;** 1=less than 20 percent, 2=20-40 percent, 3=40-60 percent, 4=60-80 percent ,5= more than 80 percent

**V12;** 1=worst, 2=bad, 3=undecided, 4=good and 5=very good

**V13;** 1= never, 2=rarely (2-3 times), 3=occasionally (4 times), 4=frequently (more than 5 times)

Table D-3 Environment Variables of Each Zone in KPP

| Zone | V14= Perception of drained water quality | V15= Perception of soil quality | V16= Satisfaction on water quality | V17= Satisfaction on soil fertility | V18= Crop residue treatment method |
|---|---|---|---|---|---|
| 1 | 3.03 | 2.13 | 4.03 | 3.92 | 2 |
| 2 | 3.83 | 2.75 | 3.74 | 3.40 | 3 |
| 3 | 2.98 | 2.93 | 3.04 | 3.00 | 3 |
| 4 | 4.32 | 3.72 | 3.62 | 3.47 | 3 |
| 5 | 4.32 | 3.72 | 3.62 | 3.47 | 3 |
| 6 | 3.84 | 4.27 | 3.71 | 3.59 | 2 |
| 7 | 2.36 | 2.49 | 3.34 | 3.38 | 2 |
| 8 | 3.24 | 3.24 | 3.29 | 3.29 | 2 |
| 9 | 3.66 | 4.15 | 3.93 | 3.75 | 2 |
| 10 | 4.00 | 4.37 | 3.79 | 3.63 | 2 |
| 11 | 3.85 | 3.92 | 4.00 | 3.95 | 3 |
| 12 | 4.07 | 4.14 | 4.39 | 3.42 | 2 |
| 13 | 3.66 | 4.15 | 3.93 | 3.75 | 2 |
| 14 | 3.67 | 4.35 | 4.06 | 3.47 | 2 |
| 15 | 5.00 | 4.60 | 4.93 | 4.93 | 2 |
| 16 | 3.83 | 3.63 | 3.89 | 3.61 | 2 |
| 17 | 3.74 | 4.12 | 3.96 | 3.56 | 2 |
| 18 | 3.71 | 3.74 | 4.29 | 3.74 | 2 |
| 19 | 4.32 | 3.91 | 4.57 | 3.74 | 2 |
| 20 | 3.92 | 3.68 | 3.85 | 3.35 | 2 |
| 21 | 4.13 | 4.10 | 4.17 | 3.44 | 2 |
| 22 | 3.86 | 3.97 | 3.91 | 3.35 | 2 |
| 23 | 3.85 | 3.70 | 3.80 | 3.38 | 2 |
| 24 | 4.02 | 3.77 | 4.93 | 4.07 | 1 |
| 25 | 3.95 | 3.74 | 4.05 | 3.72 | 3 |
| 26 | 3.92 | 3.92 | 4.29 | 4.05 | 2 |
| 27 | 3.96 | 3.86 | 4.49 | 3.96 | 1 |

The meaning of variable (V)

**V14;** 1=worst, 2=bad, 3=undecided, 4=good and 5=very good
**V15;** 1=worst, 2=bad, 3=undecided, 4=good and 5=very good
**V16;** 1=Strongly dissatisfied, 2= Dissatisfied, 3= Neutral, 4= Satisfied, 5= Strongly satisfied
**V17;** 1=Strongly dissatisfied, 2= Dissatisfied, 3= Neutral, 4= Satisfied, 5= Strongly satisfied
**V18;** 1=mainly burned, 2=mainly returned to the soil, 3=mainly used as forage and 4=other

Table D-4 Institutional Variables of Each Zone in KPP

| Zone | V19= Cultivated areas survey by WUG before irrigation season | V20= Planning of water delivery schedule by RID staffs and WUG | V21=Meeting between Chief of WUG and WUG for schedule planning agreement | V22= Listen to the opinion of WUG listening by RID staffs | V23= Announcement of the irrigation schedule to all WUG |
|---|---|---|---|---|---|
| 1 | 4.93 | 3.98 | 3.05 | 4.00 | 3.98 |
| 2 | 1.10 | 1.23 | 1.23 | 2.60 | 2.20 |
| 3 | 2.78 | 3.18 | 2.60 | 3.16 | 3.29 |
| 4 | 2.92 | 3.46 | 3.05 | 4.03 | 3.49 |
| 5 | 2.92 | 3.46 | 3.05 | 4.03 | 3.49 |
| 6 | 2.61 | 2.66 | 2.41 | 2.70 | 2.68 |
| 7 | 2.98 | 3.00 | 2.91 | 3.52 | 3.33 |
| 8 | 3.06 | 2.94 | 2.85 | 3.09 | 2.12 |
| 9 | 1.96 | 1.98 | 2.21 | 3.51 | 3.40 |
| 10 | 3.39 | 3.40 | 3.23 | 3.80 | 3.61 |
| 11 | 3.00 | 3.31 | 3.31 | 3.80 | 3.25 |
| 12 | 3.29 | 3.54 | 3.45 | 3.97 | 3.44 |
| 13 | 1.96 | 1.98 | 2.21 | 3.51 | 3.40 |
| 14 | 3.07 | 3.13 | 3.20 | 3.93 | 3.67 |
| 15 | 4.20 | 4.17 | 4.17 | 4.20 | 4.20 |
| 16 | 3.47 | 3.32 | 3.35 | 3.73 | 3.38 |
| 17 | 3.57 | 3.74 | 3.71 | 3.88 | 3.64 |
| 18 | 3.13 | 3.29 | 3.20 | 3.60 | 3.65 |
| 19 | 2.70 | 3.11 | 3.32 | 3.73 | 3.64 |
| 20 | 3.38 | 3.35 | 3.33 | 3.35 | 3.33 |
| 21 | 3.16 | 3.11 | 3.22 | 3.62 | 3.59 |
| 22 | 3.03 | 3.38 | 3.10 | 3.77 | 3.24 |
| 23 | 2.74 | 2.88 | 2.63 | 3.38 | 3.10 |
| 24 | 3.98 | 3.70 | 3.42 | 3.53 | 3.37 |
| 25 | 3.84 | 3.90 | 3.79 | 3.60 | 3.64 |
| 26 | 3.63 | 3.41 | 3.46 | 3.50 | 3.07 |
| 27 | 4.00 | 3.87 | 3.53 | 3.37 | 3.19 |

The meaning of variable (V)

**(V19,V20,V21,V22 andV23);** 1=Strongly dissatisfied, 2= Dissatisfied, 3= Neutral, 4= Satisfied, 5= Strongly satisfied

Table D-4 (Cont.)

| Zone | V24= Adequacy of water distribution | V25= Matching of farm operations with RID water delivery | V26= Reliability of continuous flow | V27= Accountability of timeliness and fairness of water distribution |
|---|---|---|---|---|
| 1 | 4.00 | 4.00 | 4.00 | 3.98 |
| 2 | 2.67 | 3.15 | 3.83 | 3.80 |
| 3 | 2.98 | 3.42 | 3.73 | 3.09 |
| 4 | 3.05 | 3.38 | 3.92 | 3.08 |
| 5 | 3.05 | 3.38 | 3.92 | 3.08 |
| 6 | 2.90 | 3.00 | 3.10 | 2.90 |
| 7 | 3.36 | 3.33 | 3.57 | 3.11 |
| 8 | 2.67 | 3.36 | 3.42 | 3.12 |
| 9 | 3.51 | 3.63 | 3.67 | 3.60 |
| 10 | 3.55 | 3.55 | 3.62 | 3.70 |
| 11 | 1.17 | 3.95 | 4.00 | 3.93 |
| 12 | 3.82 | 4.04 | 4.46 | 3.66 |
| 13 | 3.51 | 3.63 | 3.67 | 3.60 |
| 14 | 3.40 | 3.47 | 3.33 | 3.40 |
| 15 | 4.20 | 4.17 | 4.17 | 4.17 |
| 16 | 3.68 | 3.89 | 3.87 | 3.54 |
| 17 | 3.44 | 4.07 | 4.21 | 3.93 |
| 18 | 3.64 | 3.68 | 3.41 | 3.45 |
| 19 | 3.72 | 3.58 | 3.82 | 3.74 |
| 20 | 3.44 | 3.52 | 3.55 | 3.11 |
| 21 | 3.30 | 3.81 | 3.92 | 3.67 |
| 22 | 3.55 | 3.45 | 3.83 | 3.44 |
| 23 | 3.36 | 3.31 | 3.51 | 3.36 |
| 24 | 3.38 | 3.33 | 3.33 | 3.48 |
| 25 | 3.50 | 3.55 | 3.60 | 3.60 |
| 26 | 3.68 | 3.34 | 4.21 | 4.11 |
| 27 | 3.23 | 3.21 | 3.34 | 3.44 |

The meaning of variable (V)

**(V24,V25,V26 andV27);** 1=Strongly dissatisfied, 2= Dissatisfied, 3= Neutral, 4= Satisfied, 5= Strongly satisfied

Table D-4 (Cont.)

| Zone | V28= Water delivery planning process | V29=Willingness to pay | V30= Communication between farmer and RID staff |
|---|---|---|---|
| 1 | 4.00 | 2.86 | 3.95 |
| 2 | 2.10 | 1.00 | 4.00 |
| 3 | 3.04 | 2.80 | 3.93 |
| 4 | 3.38 | 2.38 | 3.78 |
| 5 | 3.38 | 2.38 | 3.78 |
| 6 | 2.70 | 2.00 | 3.09 |
| 7 | 3.18 | 3.00 | 1.16 |
| 8 | 3.00 | 2.00 | 2.53 |
| 9 | 2.98 | 3.53 | 1.66 |
| 10 | 3.61 | 2.44 | 2.36 |
| 11 | 3.49 | 1.00 | 1.37 |
| 12 | 3.74 | 1.69 | 3.72 |
| 13 | 2.98 | 3.53 | 1.66 |
| 14 | 3.53 | 2.67 | 2.74 |
| 15 | 4.20 | 3.00 | 3.50 |
| 16 | 3.49 | 1.35 | 2.63 |
| 17 | 3.79 | 1.54 | 2.71 |
| 18 | 3.43 | 1.89 | 2.58 |
| 19 | 3.43 | 3.90 | 3.05 |
| 20 | 3.35 | 1.25 | 1.42 |
| 21 | 3.45 | 3.00 | 2.40 |
| 22 | 3.32 | 2.80 | 2.16 |
| 23 | 3.17 | 2.00 | 3.28 |
| 24 | 3.70 | 4.67 | 1.53 |
| 25 | 3.84 | 1.40 | 3.74 |
| 26 | 3.70 | 2.47 | 2.63 |
| 27 | 3.67 | 3.00 | 1.40 |

The meaning of variable (V)

**V28;** 1=Strongly dissatisfied, 2= Dissatisfied, 3= Neutral, 4= Satisfied, 5= Strongly satisfied
**V29;** 1=Very Low, 2=Low, 3=Undecided, 4= High, 5= Very high
**V30;** 1=Telephone, 2= Letter, 3= WUA, 4= Personal, 5= Other (specify)

Table D-5 Physical Variables of Each Zone in PPP

| Zone | V1= Location of Sub-Main Canal in the Field | V2= Relative Position of Irrigated Area to Water Resource | V3= Ditch condition (clean/smooth) | V4= Drainage ditch condition (clean/smooth) | V5= Flooding frequency |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 3.00 | 3.00 | 4 |
| 2 | 2 | 2 | 3.19 | 3.20 | 3 |
| 3 | 2 | 3 | 3.03 | 3.32 | 4 |
| 4 | 2 | 3 | 3.00 | 3.00 | 4 |
| 5 | 2 | 3 | 3.08 | 3.04 | 4 |
| 6 | 2 | 3 | 2.97 | 2.87 | 4 |
| 7 | 2 | 3 | 2.73 | 2.68 | 4 |
| 8 | 3 | 2 | 3.41 | 3.31 | 2 |
| 9 | 2 | 2 | 3.00 | 3.00 | 2 |
| 10 | 2 | 3 | 3.06 | 3.03 | 3 |
| 11 | 2 | 3 | 3.17 | 3.09 | 2 |

The meaning of variable (V)
**V1;** 1= Upstream, 2=Middle, 3= Downstream
**V2;** 1=Higher slope, 2=Average the same level, 3=Lower slope
**V3,V4;** 1=Strongly dissatisfied, 2= Dissatisfied, 3= Neutral, 4= Satisfied, 5= Strongly satisfied
**V5;** 1=no flood within 2-3 recent years, 2=every year, 3=twice a year, 4=dependent on depression , 5=occasionally

Table D-6 Socio-Economic Variables of Each Zone in PPP

| Zone | V6=Sex | V7=Age structure | V8= Education level | V9=Experience of farmer | V10=House hold size |
|---|---|---|---|---|---|
| 1 | 1 | 3.21 | 2.09 | 3.09 | 2.15 |
| 2 | 1 | 2.82 | 2.18 | 2.55 | 2.23 |
| 3 | 1 | 3.32 | 2.23 | 2.56 | 2.54 |
| 4 | 1 | 3.85 | 2.03 | 3.05 | 2.85 |
| 5 | 1 | 3.00 | 2.26 | 2.20 | 2.60 |
| 6 | 1 | 2.68 | 2.26 | 2.10 | 2.41 |
| 7 | 1 | 2.90 | 2.03 | 1.98 | 2.50 |
| 8 | 1 | 3.31 | 2.29 | 2.26 | 2.79 |
| 9 | 1 | 2.71 | 2.07 | 2.32 | 2.75 |
| 10 | 1 | 2.88 | 2.22 | 1.58 | 2.55 |
| 11 | 1 | 3.04 | 2.30 | 1.83 | 2.78 |

The meaning of variable (V)

**V6;** 1=Male, 2=Female
**V7;** 1=less than 35 years, 2=35-45 years, 3=46-55 years, 4=56-65 years, 5= more than 65 years
**V8;** 1=no education, 2=elementary, 3=secondary, 4=high school, 5=college/university, 6 more than university
**V9;** 1=less than 15 years, 2=15-26 years, 3=26-35 years, 4=36-45 years, 5= more than 45 years
**V10;** 1=less than 2 persons, 2=3-4 persons, 3=5-6 persons, 4=7-8 persons, 5= more than 9 persons

Table D-6 (Cont.)

| Zone | V11=Land tenure | V12=Awareness on water use | V13=Water user conflict occurrence |
|---|---|---|---|
| 1 | 2.82 | 4.00 | 1.00 |
| 2 | 2.04 | 4.16 | 1.86 |
| 3 | 2.66 | 3.59 | 1.74 |
| 4 | 4.43 | 4.00 | 1.11 |
| 5 | 1.97 | 3.73 | 1.44 |
| 6 | 2.31 | 3.74 | 1.45 |
| 7 | 3.22 | 3.80 | 2.00 |
| 8 | 6.27 | 3.78 | 1.04 |
| 9 | 1.64 | 4.04 | 1.00 |
| 10 | 2.56 | 4.07 | 1.05 |
| 11 | 2.55 | 4.05 | 1.13 |

The meaning of variable (V)
**V11;** 1=less than 20 percent, 2=20-40 percent, 3=40-60 percent, 4=60-80 percent ,5= more than 80 percent
**V12;** 1=worst, 2=bad, 3=undecided, 4=good and 5=very good
**V13;** 1=never, 2=rarely (2-3 times), 3=occasionally (4 times), 4=frequently (more than 5 times)

Table D-7 Environment Variables of Each Zone in PPP

| Zone | V14= Perception of drained water quality | V15= Perception of soil quality | V16= Satisfaction on water quality | V17= Satisfaction on soil fertility | V18= Crop residue treatment method |
|---|---|---|---|---|---|
| 1 | 4.00 | 4.00 | | 3.00 | 1 |
| 2 | 3.55 | 3.50 | 3.83 | 3.91 | 1 |
| 3 | 3.67 | 3.68 | 3.35 | 3.03 | 1 |
| 4 | 3.00 | 3.53 | 3.55 | 3.53 | 1 |
| 5 | 3.54 | 3.79 | 3.51 | 3.30 | 1 |
| 6 | 3.28 | 2.95 | 3.64 | 3.53 | 1 |
| 7 | 2.30 | 2.00 | 3.80 | 3.43 | 1 |
| 8 | 3.27 | 3.57 | 3.61 | 3.42 | 1 |
| 9 | 3.81 | 3.78 | 3.96 | 3.92 | 1 |
| 10 | 3.69 | 3.67 | 3.95 | 3.87 | 1 |
| 11 | 3.91 | 4.00 | 3.91 | 3.95 | 1 |

The meaning of variable (V)
**V14;** 1=worst, 2=bad, 3=undecided, 4=good and 5=very good
**V15;** 1=worst, 2=bad, 3=undecided, 4=good and 5=very good
**V16;** 1=Strongly dissatisfied, 2= Dissatisfied, 3= Neutral, 4= Satisfied, 5= Strongly satisfied
**V17;** 1=Strongly dissatisfied, 2= Dissatisfied, 3= Neutral, 4= Satisfied, 5= Strongly satisfied
**V18;** 1=mainly burned, 2=mainly returned to the soil, 3=mainly used as forage and 4=other

Table D-8 Institutional Variables of Each Zone in PPP

| Zone | V19= Cultivated areas survey by WUG before irrigation season | V20= Planning of water delivery schedule by RID staffs and WUG | V21= Meeting between Chief of WUG and WUG for schedule planning agreement | V22= Listen to the opinion of WUG listening by RID staffs | V23= Announcement of the irrigation schedule to all WUG |
|---|---|---|---|---|---|
| 1 | 4.00 | 4.00 | 3.00 | 4.00 | 3.85 |
| 2 | 2.95 | 3.41 | 2.75 | 3.67 | 3.31 |
| 3 | 3.94 | 3.97 | 3.85 | 3.38 | 3.24 |
| 4 | 4.00 | 3.00 | 4.00 | 4.05 | 3.00 |
| 5 | 2.25 | 2.39 | 2.31 | 2.69 | 2.63 |
| 6 | 3.54 | 3.56 | 3.28 | 3.50 | 3.11 |
| 7 | 3.30 | 3.03 | 2.98 | 3.15 | 3.63 |
| 8 | 2.77 | 2.93 | 3.30 | 3.50 | 4.00 |
| 9 | 2.93 | 2.85 | 2.85 | 3.15 | 2.93 |
| 10 | 2.54 | 2.52 | 2.38 | 3.98 | 2.64 |
| 11 | 2.18 | 2.23 | 2.17 | 3.45 | 2.57 |

The meaning of variable (V)

**(V19,V20,V21,V22 andV23);** 1=Strongly dissatisfied, 2= Dissatisfied, 3= Neutral, 4= Satisfied, 5= Strongly satisfied

Table D-8 (Cont.)

| Zone | V24= Adequacy of water distribution | V25= Matching of farm operations with RID water delivery | V26= Reliability of continuous flow | V27= Accountability of timeliness and fairness of water distribution |
|---|---|---|---|---|
| 1 | 3.00 | 4.00 | 4.00 | 4.00 |
| 2 | 3.69 | 3.80 | 3.85 | 3.55 |
| 3 | 3.21 | 3.65 | 3.65 | 3.32 |
| 4 | 3.00 | 3.16 | 4.53 | 3.89 |
| 5 | 3.17 | 3.53 | 3.61 | 3.51 |
| 6 | 3.22 | 3.39 | 3.67 | 3.45 |
| 7 | 3.62 | 3.40 | 3.93 | 3.35 |
| 8 | 4.09 | 4.02 | 4.19 | 3.72 |
| 9 | 3.00 | 3.59 | 4.00 | 3.96 |
| 10 | 3.00 | 4.03 | 4.17 | 4.15 |
| 11 | 2.59 | 3.57 | 3.70 | 3.64 |

The meaning of variable (V)

**(V24,V25,V26 andV27);** 1=Strongly dissatisfied, 2= Dissatisfied, 3= Neutral, 4= Satisfied, 5= Strongly satisfied

Table D-8 (Cont.)

| Zone | V28= Water delivery planning process | V29=Willingness to pay | V30= Communication between farmer and RID staff |
|---|---|---|---|
| 1 | 3.00 | 4.00 | 4.00 |
| 2 | 3.69 | 3.80 | 3.85 |
| 3 | 3.21 | 3.65 | 3.65 |
| 4 | 3.00 | 3.16 | 4.53 |
| 5 | 3.17 | 3.53 | 3.61 |
| 6 | 3.22 | 3.39 | 3.67 |
| 7 | 3.62 | 3.40 | 3.93 |
| 8 | 4.09 | 4.02 | 4.19 |
| 9 | 3.00 | 3.59 | 4.00 |
| 10 | 3.00 | 4.03 | 4.17 |
| 11 | 2.59 | 3.57 | 3.70 |

The meaning of variable (V)

**V28;** 1=Strongly dissatisfied, 2= Dissatisfied, 3= Neutral, 4= Satisfied, 5= Strongly satisfied
**V29;** 1=Very Low, 2=Low, 3=Undecided, 4= High, 5= Very high
**V30;** 1=Telephone, 2= Letter, 3= WUA, 4= Personal, 5= Other (specify)

## Appendix E: Statistical Outputs

Table E-1 Statistic Value of Variables Used in KPP (Wet Season)

| **Variables** | Mean | Std. Deviation | Asymp. Sig. (2-tailed)* |
|---|---|---|---|
| Rain_wet | 106.2 | 2.95 | 0.182 |
| Tmean_wet | 27.37 | 0.27 | 0.002 |
| Rh_wet | 73.25 | 0.19 | 0.103 |
| Soil fertility | 3 | 0.4 | 0.000 |
| Flow ratio_wet | 4 | 1 | 0.040 |
| Field application ratio_wet | 4 | 1 | 0.040 |
| Topography (elevation) | 8.46 | 4.15 | 0.764 |
| Location of sub-main canal in the field | 2 | 0.542 | 0.001 |
| Number of staff | 4 | 2 | 0.260 |
| Work load of staff | 0.003 | 0.001 | 0.349 |
| Soil property_(pH) | 6.16 | 0.47 | 0.964 |
| Soil property_(Ec) | 0.39 | 0.24 | 0.514 |
| Irrigation water quality_(pH)_wet | 7.2 | 0.4 | 0.997 |
| Irrigation water quality_(Ec)_wet | 227.1 | 4.6 | 0.220 |
| Irrigation water quality_(TDS)_wet | 110.4 | 2.7 | 0.118 |
| Irrigation water quality_(DO)_wet | 7.1 | 0.2 | 0.488 |
| Age structure | 3 | 0.7 | 0.005 |
| Experience of farmer | 2 | 0.97 | 0.047 |
| Household member | 3 | 0.5 | 0.003 |
| Land tenure | 4 | 1.0 | 0.106 |
| Crop yield_wet | 4 | 0.8 | 0.003 |
| Production cost_wet (Baht/Ha) | 30845 | 5992 | 0.724 |
| Farm income_wet (Baht/Ha) | 67271 | 10012 | 0.944 |
| Net farm income_wet (Baht/Ha) | 36184 | 7894 | 0.214 |
| B/C_wet | 1.29 | 0.34 | 0.597 |

*One-Sample Kolmogorov-Smirnov Test

Table E-2 Statistic Value of Variables Used in KPP (Dry Season)

| **Variables** | Mean | Std. Deviation | Asymp. Sig. (2-tailed)* |
|---|---|---|---|
| Rain_dry | 53.2 | 3.23 | 0.535 |
| Tmean_dry | 28.83 | 0.06814598 | 0.172 |
| Rh_dry | 68.71 | 0.509678408 | 0.806 |
| Soil fertility | 3 | 0.4 | 0.000 |
| Flow ratio_dry | 4 | 1 | 0.120 |
| Field application ratio_dry | 4 | 1 | 0.120 |
| Topography (elevation) | 8.46 | 4.15 | 0.764 |
| Location of sub-main canal in the field | 2 | 0.542 | 0.001 |
| Number of staff | 4 | 2 | 0.260 |
| Work load of staff | 0.003 | 0.001 | 0.349 |
| Soil property_(pH) | 6.16 | 0.47 | 0.964 |
| Soil property_(Ec) | 0.39 | 0.24 | 0.514 |
| Irrigation water quality_(pH)_dry | 7.6 | 0.5 | 0.132 |
| Irrigation water quality_(Ec)_dry | 193.0 | 14.3 | 0.023 |
| Irrigation water quality_(TDS)_dry | 91.0 | 3.0 | 0.551 |
| Irrigation water quality_(DO)_dry | 7.6 | 0.3 | 0.795 |
| Age structure | 3 | 0.7 | 0.005 |
| Experience of farmer | 2 | 0.97 | 0.047 |
| Household member | 3 | 0.5 | 0.003 |
| Land tenure | 4 | 1.0 | 0.106 |
| Crop yield_dry | 4 | 0.8 | 0.010 |
| Production cost_dry (Baht/Ha) | 30323 | 5960 | 0.610 |
| Farm income_dry (Baht/Ha) | 69207 | 9227 | 0.906 |
| Net farm income_dry (Baht/Ha) | 38883 | 6935 | 0.631 |
| B/C_dry | 1.39 | 0.31 | 0.800 |

*One-Sample Kolmogorov-Smirnov Test

Table E-3 Statistic Value of Variables Used in PPP (Wet Season)

| **Variables** | Mean | Std. Deviation | Asymp. Sig. (2-tailed)* |
|---|---|---|---|
| Rain_wet | 103.5 | 15.06 | 0.419 |
| Tmean_wet | 27.31 | 0.16 | 0.127 |
| Rh_wet | 75.23 | 0.88 | 0.255 |
| Flow ratio_wet | 4 | 1 | 0.367 |
| Field application ratio_wet | 4 | 1 | 0.367 |
| Topography (elevation) | 6.34 | 1.93 | 0.973 |
| Location of sub-main canal in the field | 2 | 0.6 | 0.000 |
| Number of staff | | | |
| Work load of staff | 0.001 | 0.0002 | 0.700 |
| Soil property_(pH) | 5.04 | 0.27 | 0.973 |
| Soil property_(Ec) | 0.39 | 0.12 | 0.830 |
| Irrigation water quality_(pH)_wet | 7.5 | 0.3 | 0.960 |
| Irrigation water quality_(Ec)_wet | 226.0 | 2.4 | 0.648 |
| Irrigation water quality_(TDS)_wet | 110.0 | 2.1 | 0.968 |
| Irrigation water quality_(DO)_wet | 7.0 | 0.3 | 0.904 |
| Age structure | 3 | 0.30 | 0.004 |
| Experience of farmer | 2 | 0.50 | 0.058 |
| Household member | 3 | 0.47 | 0.024 |
| Land tenure | 3 | 0.94 | 0.355 |
| Crop yield_wet | 3 | 0.45 | 0.050 |
| Production cost_wet (Baht/Ha) | 36276 | 3606 | 0.874 |
| Farm income_wet (Baht/Ha) | 65575 | 8474 | 0.997 |
| Net farm income_wet (Baht/Ha) | 29300 | 5598 | 0.612 |
| B/C_wet | 0.83 | 0.11 | 0.959 |

*One-Sample Kolmogorov-Smirnov Test

Table E-4 Statistic Value of Variables Used in PPP (Dry Season)

| **Variables** | Mean | Std. Deviation | Asymp. Sig. (2-tailed)* |
|---|---|---|---|
| Rain_dry | 50.5 | 8.84 | 0.683 |
| Tmean_dry | 28.56 | 0.09 | 0.088 |
| Rh_dry | 70.35 | 1.26 | 0.259 |
| Flow ratio_dry | 3 | 1 | 0.355 |
| Field application ratio_dry | 3 | 1 | 0.355 |
| Topography (elevation) | 6.34 | 1.929 | 0.973 |
| Location of sub-main canal in the field | 2 | 0.607 | 0.000 |
| Number of staff | | | |
| Work load of staff | 0.001 | 0.000 | 0.700 |
| Soil property_(pH) | 5.04 | 0.27 | 0.973 |
| Soil property_(Ec) | 0.39 | 0.12 | 0.830 |
| Irrigation water quality_(pH)_dry | 7.9 | 0.3 | 0.342 |
| Irrigation water quality_(Ec)_dry | 194.2 | 6.4 | 0.549 |
| Irrigation water quality_(TDS)_dry | 92.1 | 2.1 | 0.752 |
| Irrigation water quality_(DO)_dry | 7.6 | 0.3 | 0.861 |
| Age structure | 3 | 0.3 | 0.004 |
| Experience of farmer | 2 | 0.50 | 0.058 |
| Household member | 3 | 0.5 | 0.024 |
| Land tenure | 3 | 0.9 | 0.355 |
| Crop yield_dry | 3 | 0.40 | 0.010 |
| Production cost_dry (Baht/Ha) | 36327 | 3756 | 0.880 |
| Farm income_dry (Baht/Ha) | 67694 | 6100 | 0.674 |
| Net farm income_dry (Baht/Ha) | 31367 | 3539 | 0.924 |
| B/C_dry | 0.90 | 0.10 | 0.995 |

*One-Sample Kolmogorov-Smirnov Test

Table E-5 Outputs of Reliability Test in KPP

| Variable | Scale Mean if Item Deleted | Scale Variance if Item Deleted | Corrected Item Total Correlation | Alpha if Item Deleted |
|---|---|---|---|---|
| Cultivated areas survey by WUG before irrigation season | 64.6722 | 31.7317 | .3486 | .7003 |
| Planning of water delivery schedule by RID staffs and WUG | 64.5694 | 31.9484 | .3639 | .6995 |
| Meeting between Chief of WUG and WUG for schedule planning agreement | 64.6555 | 31.4254 | .4419 | .6930 |
| Listen to the opinion of WUG listening by RID staffs | 64.2225 | 31.4060 | .5362 | .6884 |
| Announcement of the irrigation schedule to all WUG | 64.5431 | 31.5389 | .4139 | .6951 |
| Accountability of timeliness and fairness of water distribution | 64.2697 | 30.7770 | .4916 | .6875 |
| Satisfaction on adequacy of water distribution | 64.3780 | 31.6122 | .4093 | .6956 |
| Matching of farm operations with RID water delivery | 64.1770 | 32.7072 | .3307 | .7034 |
| Reliability of continuous flow | 63.9665 | 32.1859 | .3780 | .6992 |
| Drainage ditch condition (clean/smooth) | 64.7727 | 31.9986 | .3259 | .7024 |
| Canal/ditch condition (clean/smooth) | 64.8923 | 32.6095 | .2722 | .7073 |
| Water user conflict occurrence | 64.4187 | 34.7140 | .0270 | .7266 |
| Awareness on water use | 63.7536 | 33.1358 | .2272 | .7109 |
| Perception on soil erosion | 64.4641 | 30.8248 | .3582 | .6987 |
| Satisfaction on promotion of RID staff | 65.5813 | 39.6972 | -.5946 | .7658 |
| Willingness to pay | 65.6148 | 31.2734 | .1767 | .7291 |
| Perception on drained water quality | 64.0407 | 32.7921 | .2313 | .7110 |
| Perception on soil quality | 64.0144 | 32.6665 | .2617 | .7082 |
| Satisfaction on quality of irrigation water | 63.8230 | 31.0717 | .5273 | .6869 |
| Satisfaction on soil fertility of irrigable area | 64.2177 | 32.4201 | .3412 | .7020 |

***Alpha = 0 .7170***

Table E-6 Outputs of Test Reliability of PPP

| Variable | Scale Mean if Item Deleted | Scale Variance if Item Deleted | Corrected Item Total Correlation | Alpha if Item Deleted |
|---|---|---|---|---|
| Cultivated areas survey by WUG before irrigation season | 60.2000 | 25.3481 | .4217 | .6631 |
| Planning of water delivery schedule by RID staffs and WUG | 60.0182 | 25.3145 | .4638 | .6586 |
| Meeting between Chief of WUG and WUG for schedule planning agreement | 60.3091 | 27.0323 | .2770 | .6809 |
| Listen to the opinion of WUG listening by RID staffs | 59.9455 | 25.7192 | .5468 | .6546 |
| Announcement of the irrigation schedule to all WUG | 60.1818 | 26.4848 | .6472 | .6571 |
| Accountability of timeliness and fairness of water distribution | 59.8000 | 29.3111 | .0442 | .7006 |
| Satisfaction on adequacy of water distribution | 59.9273 | 28.1798 | .2630 | .6831 |
| Matching of farm operations with RID water delivery | 59.6545 | 28.7118 | .1548 | .6912 |
| Reliability of continuous flow | 59.5818 | 28.3219 | .1901 | .6887 |
| Drainage ditch condition (clean/smooth) | 59.8909 | 27.8397 | .2687 | .6820 |
| Canal/ditch condition (clean/smooth) | 59.9818 | 27.9811 | .2530 | .6834 |
| Water user conflict occurrence | 61.4545 | 27.4747 | .3440 | .6759 |
| Awareness on water use | 59.3636 | 27.9394 | .1967 | .6889 |
| Perception on soil erosion | 59.8182 | 25.2626 | .4286 | .6621 |
| Satisfaction on promotion of RID staff | 60.0909 | 24.5286 | .6976 | .6370 |
| Willingness to pay | 61.1273 | 30.2242 | -.1121 | .7328 |
| Perception on drained water quality | 59.6182 | 28.0182 | .1527 | .6947 |
| Perception on soil quality | 59.6364 | 29.4579 | -.0065 | .7097 |
| Satisfaction on quality of irrigation water | 59.7273 | 28.3131 | .2437 | .6845 |
| Satisfaction on soil fertility of irrigable area | 59.7818 | 28.6182 | .1357 | .6936 |

***Alpha = 0 .701***

## Table E-7 Scaling of Irrigation Sustainability Index for KPP

| Zone | X1=Net farm income | X2=Awareness on irrigation water use | X3= Matching of farm operations with RID water delivery | X4=Field application ratio |
|---|---|---|---|---|
| 1 | 33,098 | 2 | 4 | 4 |
| 2 | 29,943 | 3 | 3 | 4 |
| 3 | 38,466 | 3 | 3 | 4 |
| 4 | 39,897 | 4 | 3 | 4 |
| 5 | 31,087 | 4 | 4 | 5 |
| 6 | 43,512 | 4 | 4 | 5 |
| 7 | 43,018 | 4 | 4 | 5 |
| 8 | 35,449 | 4 | 4 | 5 |
| 9 | 36,129 | 4 | 4 | 5 |
| 10 | 62,667 | 5 | 4 | 5 |
| 11 | 39,689 | 4 | 4 | 4 |
| 12 | 34,507 | 5 | 4 | 5 |
| 13 | 38,074 | 5 | 3 | 4 |
| 14 | 31,065 | 4 | 3 | 4 |
| 15 | 39,205 | 5 | 4 | 3 |
| 16 | 33,413 | 4 | 4 | 5 |
| 17 | 33,156 | 4 | 4 | 3 |
| 18 | 35,284 | 4 | 4 | 5 |
| 19 | 32,750 | 4 | 4 | 4 |
| 20 | 34,761 | 4 | 4 | 5 |
| 21 | 30,810 | 5 | 4 | 2 |
| 22 | 25,482 | 4 | 3 | 5 |
| 23 | 36,231 | 4 | 3 | 3 |
| 24 | 50,420 | 5 | 3 | 5 |
| 25 | 35,502 | 4 | 4 | 5 |
| 26 | 44,846 | 4 | 3 | 1 |
| 27 | 37,547 | 5 | 3 | 4 |

## Table E-8 Scoring of Irrigation Sustainability Index for KPP

| Zone | $X_1$=Net farm income | $X_2$=Awareness on irrigation water use | $X_3$= Matching of farm operations with RID water delivery | $X_4$=Field application ratio |
|---|---|---|---|---|
| 1 | 0.480 | 0.364 | 0.909 | 0.727 |
| 2 | 0.434 | 0.545 | 0.682 | 0.727 |
| 3 | 0.558 | 0.545 | 0.682 | 0.727 |
| 4 | 0.579 | 0.727 | 0.682 | 0.727 |
| 5 | 0.451 | 0.727 | 0.909 | 0.909 |
| 6 | 0.631 | 0.727 | 0.909 | 0.909 |
| 7 | 0.624 | 0.727 | 0.909 | 0.909 |
| 8 | 0.514 | 0.727 | 0.909 | 0.909 |
| 9 | 0.524 | 0.727 | 0.909 | 0.909 |
| 10 | 0.909 | 0.909 | 0.909 | 0.909 |
| 11 | 0.576 | 0.727 | 0.909 | 0.727 |
| 12 | 0.501 | 0.909 | 0.909 | 0.909 |
| 13 | 0.552 | 0.909 | 0.682 | 0.727 |
| 14 | 0.451 | 0.727 | 0.682 | 0.727 |
| 15 | 0.569 | 0.909 | 0.909 | 0.545 |
| 16 | 0.485 | 0.727 | 0.909 | 0.909 |
| 17 | 0.481 | 0.727 | 0.909 | 0.545 |
| 18 | 0.512 | 0.727 | 0.909 | 0.909 |
| 19 | 0.475 | 0.727 | 0.909 | 0.727 |
| 20 | 0.504 | 0.727 | 0.909 | 0.909 |
| 21 | 0.447 | 0.909 | 0.909 | 0.364 |
| 22 | 0.370 | 0.727 | 0.682 | 0.909 |
| 23 | 0.526 | 0.727 | 0.682 | 0.545 |
| 24 | 0.731 | 0.909 | 0.682 | 0.909 |
| 25 | 0.515 | 0.727 | 0.909 | 0.909 |
| 26 | 0.651 | 0.727 | 0.682 | 0.182 |
| 27 | 0.545 | 0.909 | 0.682 | 0.727 |

Table E-9 Scaling of Irrigation Sustainability Index for PPP

| Zone | $X_1$=Perception on drained water quality | $X_2$= Satisfaction on adequacy of water distribution | $X_3$=Net farm income | $X_4$= Flow ratio |
|---|---|---|---|---|
| 1 | 4 | 3 | 28,712 | 3 |
| 2 | 4 | 4 | 32,520 | 5 |
| 3 | 4 | 3 | 35,206 | 4 |
| 4 | 3 | 3 | 24,622 | 5 |
| 5 | 4 | 3 | 27,148 | 5 |
| 6 | 3 | 3 | 27,764 | 4 |
| 7 | 2 | 4 | 37,722 | 3 |
| 8 | 3 | 4 | 26,199 | 5 |
| 9 | 4 | 3 | 31,942 | 5 |
| 10 | 4 | 3 | 27,047 | 5 |
| 11 | 4 | 3 | 34,792 | 3 |

Table E-10 Scoring of Irrigation Sustainability Index for PPP

| Zone | $X_1$=Perception on drained water quality | $X_2$= Satisfaction on adequacy of water distribution | $X_3$=Net farm income | $X_4$=Flow ratio |
|---|---|---|---|---|
| 1 | 0.909 | 0.682 | 0.692 | 0.545 |
| 2 | 0.808 | 0.909 | 0.784 | 0.909 |
| 3 | 0.909 | 0.682 | 0.848 | 0.727 |
| 4 | 0.682 | 0.682 | 0.593 | 0.909 |
| 5 | 0.909 | 0.682 | 0.654 | 0.909 |
| 6 | 0.682 | 0.682 | 0.669 | 0.727 |
| 7 | 0.455 | 0.909 | 0.909 | 0.545 |
| 8 | 0.682 | 0.909 | 0.631 | 0.909 |
| 9 | 0.909 | 0.682 | 0.770 | 0.909 |
| 10 | 0.839 | 0.682 | 0.652 | 0.909 |
| 11 | 0.909 | 0.682 | 0.838 | 0.545 |

## Appendix F: Photos of Infrastructure and Field Activities

Figure F-1 Location of Kamphaengsaen O&M project (KPP)

Figure F-2 Meeting of zonemen at water allocation section 2 in KPP

Figure F-3 Participation of WUGs on irrigation improvement

Figure F-4 Meeting of farmers and respondents in zone 19 and zone 10

Figure F-5 Gate regulator at canal 1L-5L in KPP

Figure F-6 Illegal pipe for pumping water from canal in KPP

Figure F-7 Fertilizer application and crop spraying of farmers in KPP

Figure F-8 Phophraya O&M project (PPP)

Figure F-9 Upstream location of canal 1L in PPP

Figure F-10 Rice harvesting in PPP

Figure F-11 Rice lodging during rainy season in PPP

Figure F-12 Stubble of rice and rice (first stage) at the same field

Figure F-13 Weed removal by farmer at farm turn out gate in PPP

Figure F-14 Illegal pipe in PPP

Figure F-15 Discussion with RID staff in PPP